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Industrial Preparedness—Explosives From The Air

ARMY ORDNANCE

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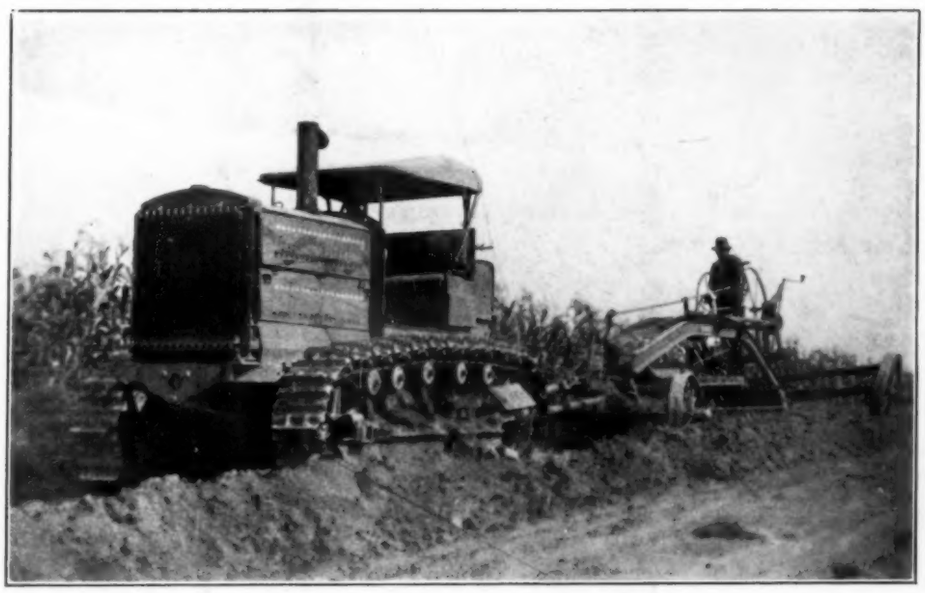

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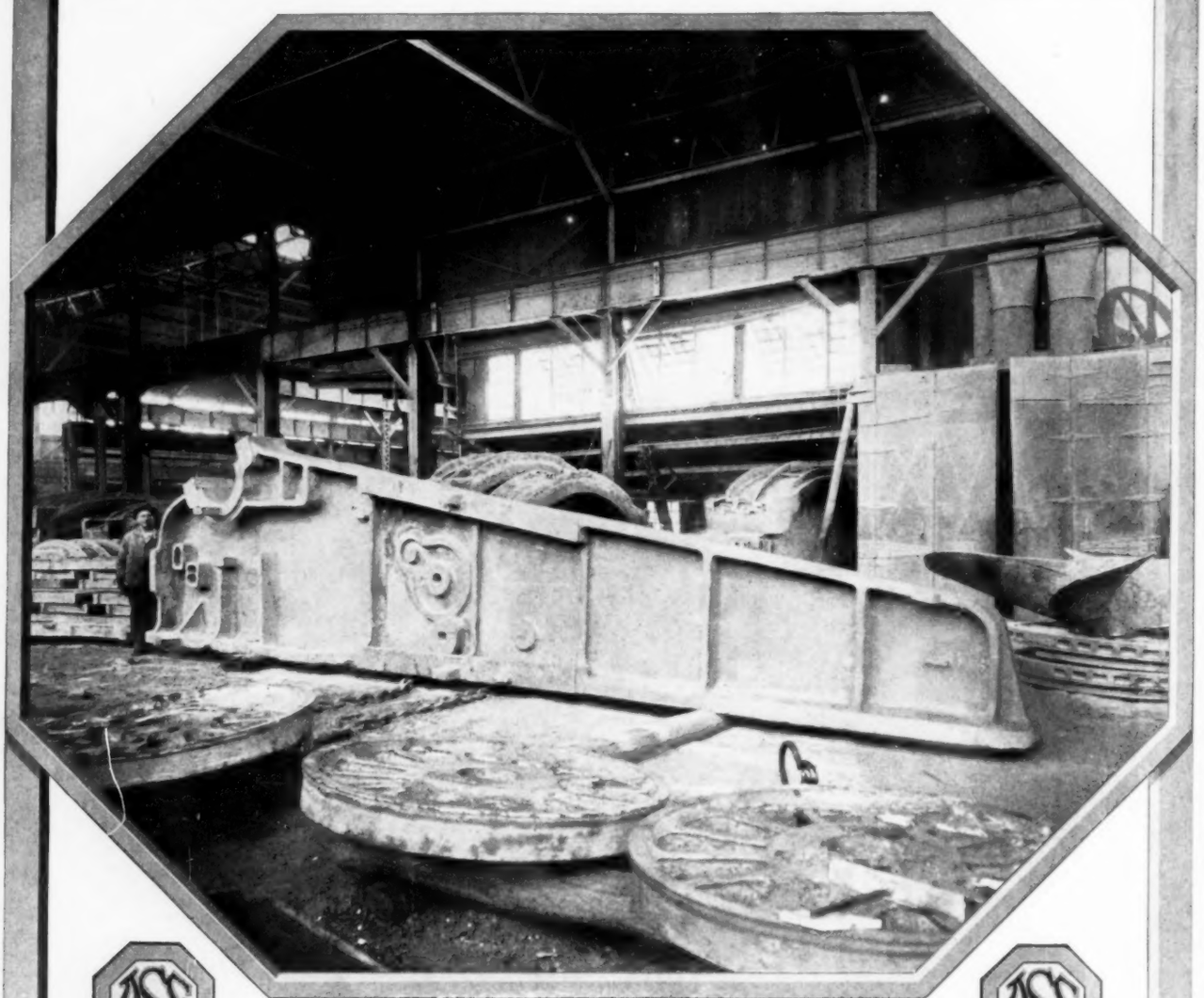

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Industrial Preparedness.

By

J. MAYHEW WAINWRIGHT

Assistant Secretary of War

THE War Department exists in time of peace only in order to be of value in time of war. The effort of training, and supplying the peace time army represents only a very small fraction of the war effort. The officer who served through the World War and failed to appreciate this outstanding fact has entirely lost one of the most valuable lessons resulting from that conflict. Before the war we saw our younger officers, and many of the older ones too, devoting their entire energy to the training of their peace organizations. This gave us one most valuable asset, namely, trained officers, but it did not give us trained organizations, because the peace units were such an extremely small leaven when merged into the enormous and multitudinous war organizations. So, too, the peace time experience and organization for the supply of our little peace army served to train our officers in technique, and to a certain extent in business methods, but there were few who grasped at that time the enormous increase in procurement effort, and the almost insurmountable difficulties which accompanied the supply of a war army with the entire nation in arms. We now see that in the supply branches, and particularly in the Ordnance Department, the war problem is the paramount issue, even in time of peace. It has been estimated that the peace effort of the Ordnance Department represents in money only one-tenth of one per cent of the war effort. So that one important thing that every officer must realize is that the War Department is organized for the purpose of waging successful war when necessary, that in time of peace it must prepare for war, and that the training and supply of the peace army is but one small item, although a most necessary and important item in this preparation. Another most important item, the one with which we are going to deal herewith, is the planning of the necessary war procurement of munitions and supplies and the necessary mobilization of our industries to effect this in wars of all magnitude.

J. Mayhew Wainwright

Historical

The outbreak of the World War found the War Department without a major emergency plan upon which could be based plans for the procurement of supplies. The European conflict had, however, gotten many of our officers and civilians thinking on broader lines than ever before, and this thought culminated in some action such as the citizens training camps of 1915 and 1916, and, from our present point of view, in the creation of a Council of National Defense by the Army appropriation act of August 29, 1916. Section 2 of this act provided "That a Council of National Defense is hereby established for the coordination of industries and resources for the national security and welfare, to consist of the Secretary of War, the Secretary of the Navy, the Secretary of the Interior, the Secretary of Agriculture, the Secretary of Commerce, and the Secretary of Labor." Another important pre-war action was the appointment of a board now known as the Kernan Board to investigate and report upon the feasibility, desirability, and practicability of the Government manufacturing arms, munitions, and equipment, and certain other allied questions. The board, which concluded its work prior to 1917, found that the utmost capacity of our several arsenals was below even the prospective peace needs of our military establishment just expanded by the National Defense Act of 1916, and that it faded into insignificance when the possible demands for war were called to mind. The board also made certain recommendations which were of considerable value in the great emergency that was to come.

The permanent organization of the Council of National Defense was effected early in March, 1917, and upon the

declaration of war the Council bent its energy to make available to the United States the best thought and effort of American industrial and professional life for the successful prosecution of the conflict. One of the first important steps was the creation by it of the General Munitions Board on April 9, 1917, the efforts of which were directed toward coordinating the making of purchases by the Army and Navy, assisting in the acquisition of raw materials, and establishing precedence of orders between the military and industrial needs of the country. Representatives of the several supply bureaus of the War and Navy Departments were members of this Board. It was the purpose of the board to exercise sufficient supervision over the distribution of Government orders to prevent competition in buying between the two departments and among the several purchasing agencies of the War Department.

In the meantime shortages began to appear in a number of trades, prices began to soar, additional war needs developed, the transportation, labor, and fuel problems became involved, and a need for determining priorities not only between the several agencies of the Government, but between the Government and civilian needs became evident. The Council of National Defense took prompt action to cure these difficulties, creating July 28, 1917, with the approval of the President, a new body to which it gave the name War Industries Board. During the summer and fall of 1917, the Food, Fuel, and Railroad Administration, the Shipping Board, and the War Trade Board were established by acts of Congress.

It is the work of the War Industries Board which particularly interests us in the present discussion. The problem confronting this board was vast and complex. The board was to act as a clearing house for the war industry needs of the Government, determine the most effective ways of meeting them and the best means and methods of increasing production, including the creation or extension of industries demanded by the emergency. It had to insure against insurmountable shortage in necessary commodities, and to cause commodities to flow in channels most conducive to the purpose of the war. It had to insure the supply of raw material, the prompt manufacture of that raw material into munitions, and finally its unimpeded flow to the ports of embarkation for the troops. It found it necessary to establish a priority system and a price-fixing plan. Various subdivisions, committees, and sub-boards were shaped to forward these purposes, the duties of each supplementing those of the others. The War Industries Board continued to function as such until the close of the war.

The Office of the Assistant Secretary

Upon the close of the war it became necessary to redraft our whole scheme of national defense in light of lessons of the past, and the present political, economic, and international situations. After prolonged study and debate Congress finally created and passed the National Defense Act of June 4, 1920, legislation which for farsightedness, sound judgment, common sense, and adherence to our national policies and ideals deserves to rank among the enduring documents of the Nation. In this act Congress undertook not only to prescribe laws which would result in the organization of an Army of the United States, capable of being trained for war and expandable in war, but also prescribed laws which created the machinery for planning the peace and war-time procurement of supplies and for the mobilization of industry in war. These latter duties fall upon the Assistant Secretary of War, he being charged under section 5a of the act with the supervision of the procurement of all military supplies and other business of the War Department pertaining thereto and the assurance of adequate provision for the mobilization of matériel and industrial organizations essential to war-time needs.

Under the above law the problem of the Assistant Secretary was to create an organization and methods which would insure that competent consideration be given to all angles of the work in such a way that the final results would be an adequate and well coordinated plan. In performing this task the Assistant Secretary of War determines general policies, and coordinates all work, but he must necessarily rely upon the Supply Services and other agencies for the accomplishment of the tasks for which in organization and in experience, they are best fitted, and for which, indeed, they are responsible. There has been organized an "Office of the Director of Procurement" in the Office of the Assistant Secretary of War. This is further divided into Current Procurement and the Planning Branch. In war the latter branch will absorb the former. The Planning Branch is organized into several divisions covering such matters as priority, allocation, price control, contracts, power, labor, transportation, facilities, and conservation in their relation to War Department procurement. The personnel in the office includes, in addition to the director and administrative officers, an officer representative from each of the supply branches of the Army. The complete records of the War Industries Board and the Council of National Defense were turned over to the Assistant Secretary of War when the office was organized on the present basis. These records form an almost complete story of the industrial side of Army procurement in the late war. It is partly from the lessons contained in these records, and partly from advice and criticism of the best business brain of the nation that the Assistant Secretary must base future procurement policy.

Planning Branches of Supply Services

We have already seen that the Assistant Secretary supervises the tasks of procurement planning and industrial preparedness in the various Supply Services. Each Supply Service in the War Department has organized a Planning Section the entire time of which is devoted to computing requirements, allocating these requirements to the various and proper facilities or plants, placing of war orders, calculation of raw material, and related matters. Thus the Planning Section in the Ordnance Department is assisted in the field by District Chiefs, who in their turn have a regular officer as executive assistant. In the Ordnance Office there are three officers in the Planning Branch. The country is divided into thirteen Ordnance industrial districts with a district chief and executive assistant in charge. The Planning Branch calculates their requirements based on the War Plan and Tables of Allowances and Equipment. In the Ordnance Department these requirements have already been calculated on 299 major items of equipment which embrace 95 per cent of the total equipment required. Based on information gathered during the late war these requirements have been tentatively allocated to various firms and plants (facilities) throughout the country, and the various district offices are starting to approach these plants for information as to the feasibility of these tentative plans and allocations. Following this a request for the permanent allocation of these facilities to the Supply Department will be made to the Assistant Secretary because the latter's office must coordinate all matters between the services and the Navy, and of course cases may arise where two supply services desire to utilize the same facility.

Then will naturally come the placing of War Orders with these plants, ready to be started into production upon declaration of war. These orders will employ the new form of Standard War Contracts now under consideration in the Assistant Secretary's office.

There are many ramifications of the work, only a few of which can be touched on here. For example, the placing of a finished product requirement with a plant also probably involves an additional requirement for machine tools to make the product, and these together involve a requirement for a number of raw materials, of labor, power and transportation. As the war plan changes, as industrial conditions change, as plants change or are converted to other lines of manufacture, so these procurement plans must change, so that there is most varied and endless work necessitating a highly trained personnel to direct it.

The War Industries Board

The National Defense Act does not give the Assistant Secretary any authority or control over industry, but it does make him responsible for certain planning. Industrial mobilization means that control will be exercised over all industries to a sufficient extent to direct all activities of the Nation to the one purpose of winning the war; it means that raw materials, transportation and power whenever shortage exists will be assigned to factories in accordance with their importance in producing either munitions for the Army or the necessaries of life for the civilian population; and it means that business enterprises not contributing toward winning the war must be curtailed to such an extent as may be necessary. The necessary control will be exercised, not by the War Department, but by certain super-agencies of a civilian character, representing the brain of our industrial life which will be organized on the outbreak of war for this purpose. Some of these super-agencies which functioned during the late war, and which will again be necessary in a war of magnitude were the War Industries Board, the Food, Fuel and Railroad Administrations, and the Shipping Board. The control agency with which the Army is most directly concerned is the War Industries Board.

In any war of major magnitude there will be a War Industries Board, or similar agency, which will exercise the necessary control over all factories and other agencies of production. Control over all War Department procuring agents will still be centered in the Assistant Secretary. Thus industrial production is organized under one head, and the War Department and Navy Department procurement is organized under other heads; the closest cooperation being necessary between all three; and all being responsible to the President, who in time of war is the Commander in Chief of Industry, the Army and the Navy.

It has been seen that the law does not give the Assistant Secretary control over industry, but that it does make him responsible for planning. In war of magnitude no military plan would be of value without a corresponding industrial plan. The Office of the Assistant Secretary, which is headed by a civilian, gives the necessary point of contact between Army and industry. It is the policy of the Assistant Secretary to secure the best opinion on all industrial questions. It is the policy to go even further than that; whenever practicable planning along a particular line is turned over absolutely to a qualified civilian agency, giving to them the military assumption upon which planning must be based. Thus the War Department plans will not be at variance with modern civilian industrial practice, and when war makes it necessary to set up certain super civilian agencies such as the War Industries Board, the War Department will be fully prepared for cooperation with them, and will, in fact, have to a great extent smoothed the way for such agencies.

Present Status

It is earnestly desired to avoid giving the impression here that the problems involved in a plan for industrial mobilization have all been solved, or that the work has been completed. This is not the case. The calculation of requirements is not yet complete nor have these requirements been translated into terms of material and labor required. The problem must not only be reduced to those terms, but the requirements for them will be distributed geographically through the logical industrial districts, and a very full study made of each one of these local situations in order to avoid the congestion in labor, power, transportation, housing, etc., that existed in several areas during the late war.

Perhaps the real value of all of this work lies in its ability to arouse and maintain interest in it and its problems in the minds of the personnel, both military and civilian, now charged with its preparation, and in the event of an emergency, to be charged with its execution. This plan, when completed, will fail of its purpose if it is locked up in a safe and dismissed from our consideration as an accomplished fact. It must be made a living thing of vital interest to many trained minds, growing and changing from year to year as it develops.

The solution of these plans will lead inevitably to one conclusion that it is desired to emphasize. It will point out inexorably our shortcomings in certain finished matériel and strategic raw materials. It will show that unless we actually construct in time of peace sufficient reserves of certain vital equipment and accumulate working reserves of strategic raw materials that we cannot produce within the continental United States, we should not be able to hold our lines during the early period of the war. As a Nation we are apparently content to assume that we shall keep control of the sea to the extent necessary to import these strategic raw materials. A plea for national defense prepared on such assumption is unsound, unless in time of peace the Navy is maintained on a basis that will enable it to keep control of the sea and so justify this assumption. In the accumulation through a period of peace of the vital equipment of munitions, we accomplish a second purpose, equally important, in that we keep alive the art of manufacture of war munitions, which, once permitted to atrophy, cannot be revised easily or quickly. Without these reserves and these facilities, the outbreak of a major emergency would find us not only unprepared, but unable to prepare.

It is, of course, not intended nor desired to sound a pessimistic note, nor is it necessary at this time to do so, but in default of adequate provision having been made for the necessary elements above referred to, we shall never be really prepared to meet successfully the task imposed upon us by a great war.

Conclusion

War has progressed from the tactical combat of organized armies to a bitter struggle by the whole Nation, involving fruits of the soil, the entire production of industry, and the efforts of every citizen at home. War can no longer be fought by the mere use of organized armies and man power. It requires in addition the mobilization of industry, full utilization of the Nation's resources, and the most efficient and organized husbanding of the Nation's man power and energy.

Pneumatic Equilibrators

By

B. P. JOYCE

Member A. O. A.

THERE appeared in the May-June, 1921, number of this publication, under Artillery Division Notes, an article on equilibration. This article pointed out the comparatively great manufacturing tolerances required in springs for equilibration, and stated that pneumatic equilibrators were contemplated which it was expected would prove better than the spring type. Pneumatic equilibrators have been built and tested which lived up to these expectations.

A detailed cross section of the first pneumatic equilibrator as built is shown in Fig. 1, and an enlarged section of its packing shown in Fig. 2. The case A contains the plunger B, whose outer surface is highly polished, the plunger being actuated by compressed nitrogen in the chamber C, which nitrogen is admitted through the valve D. The chamber E contains grease, which is admitted through the valve F, the grease serving as a lubricant as well as a seal between the compressed nitrogen and the atmosphere. The antifriction metal ring G, to which is fastened the silver cup ring H, separates the grease from the nitrogen. The ring I serves as a seat for the packing spring J and also prevents the silver ring H on the ring G from obscuring the valve F when the quantity of grease in the space E is small. The bronze ring K prevents contact of the spring J with the polished surface of the plunger B; also, it serves as a seat for the packing N. The silver cup ring L, scraping the surface of the plunger B, keeps it clean as it enters under the packing N. The silver cup rings M inclose a rubber filler N whose inner surface is lined with the leather ring O. The ring P contains the antifriction metal ring Q, and serves as a seat for the outer packing S. S is a rubber ring inclosed in two copper cup rings R. T is a filler ring. The packing is held in place by the nut U. The leather wiper V is secured by the nut W. The leather bellows X expand and contract with the movement of the plunger and protect its polished surface as it moves in and out of the case. The aluminum filler Y serves as an adjustment for the volume of the nitrogen in chamber C. The ring Z prevents accidental withdrawal of the plunger B by striking the ring G, and also aids in disassembling.

The general functioning of the parts shown in Figs. 1 and 2 are as follows: The antifriction metal rings G and Q furnish bearing for and keep the plunger B in alignment. The rubber filler N is under the spring pressure J and the nitrogen pressure in chamber C, which is exerted upon its annulus through the grease in the seal E, and transmits this pressure to its leather lining O, forcing it in contact with the polished surface of the plunger B,

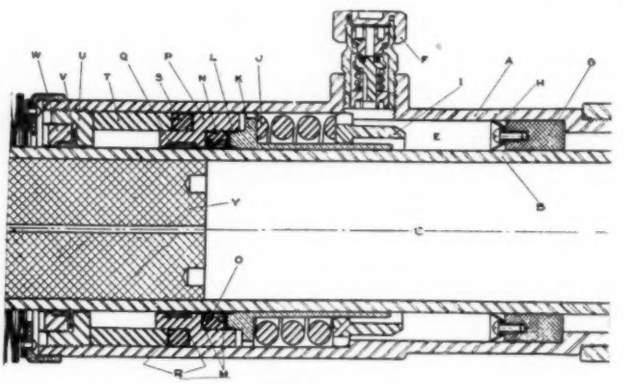


Figure 2

and so prevents any leakage of the grease from the chamber E. The pressure transmitted by the rubber filler N is considerably less than liquid pressure; therefore, the spring J is necessary in order to boost the pressure between the leather ring O and the plunger so that this pressure is slightly greater than the grease pressure in the chamber E, and so prevents leakage of the grease. The rubber filler S forms the outer seal in the stationary joint, and its tightness is insured owing to nitrogen pressure over the annulus between the plunger and the case upon its annulus. The leather wiper V prevents dirt or grit from entering the assembly from under the leather bellows X. The rubber filler N would tear and tend to creep between its silver ring and the plunger were it in contact with the plunger, which is the reason for lining its contact surface with the leather ring O.

Tests made on this equilibrator as to friction are illustrated by curves plotted in Fig. 3. Curve Y shows the calculated amount of friction which is due to the pressure of the spring J upon the packing at N. X is the friction calculated as being due to both the spring pressure J and the

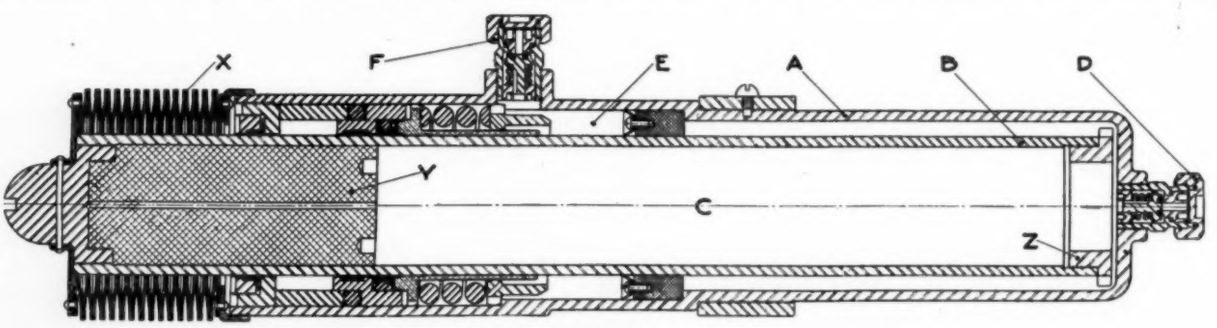


Figure 1

pressure of the nitrogen in compartment C. A is a curve of the first test of this assembly, and it is seen that it is somewhat higher than the calculated friction.

It was suggested that a metallic packing might give less friction than the packing at N. A metal packing was designed of V-shaped rings of alternate hard and soft metal whose bearing surface was approximately two inches long, this packing being substituted for the packing at N. This assembly was tested and the results are indicated by the curve B. It is seen that B is much greater than A, which brought up the question as to whether metallic packing would show less friction than the packing N.

In order to investigate this, the leather ring O was covered with two thicknesses of tin foil approximately .004 inch thick. Tests were run, the results of which are indicated by curves C and D, one with the leather ring covered with tin foil and one without it. It is seen that there is practically no difference between these curves.

In view of the above and the fact that trouble has been experienced with recuperators in storage, owing to the tanning chemicals in leather attacking and pitting the polished surfaces with which these leathers are in contact, it was determined to line all leather contact surfaces with tin foil to prevent such pitting. It was found upon gymnasticating the assembly 1,000 times that the wear on the tin foil was so slight that it could not be measured with an ordinary micrometer.

The curve E shows the first test of an equilibrator other than the one upon which the first tests were run. It is seen that the friction of this equilibrator is very high, and after a number of experiments it was found that this friction was due to the cramping of the silver ring L by the ring K. After this had been corrected, the friction curve of this equilibrator dropped to the level of the curves C and D.

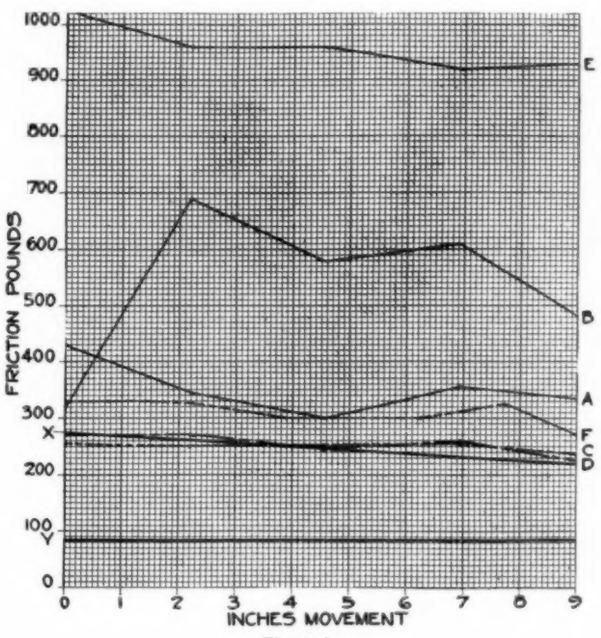


Figure 3.

The tests indicated by curves C and D were made about the middle of February, 1922. The equilibrators were then charged with nitrogen under pressure, and put under observation from that time until June, 1922. No drop in pressure of the nitrogen was noted during this period of observation which was attributable to leakage. Other tests were now run, whose results are shown by the curve F. It is seen that the friction has increased, which, upon disassembly, was attributed to absorption of grease by the rubber ring N, which caused it to enlarge and, therefore, caused greater pressure between the packing and the plunger.

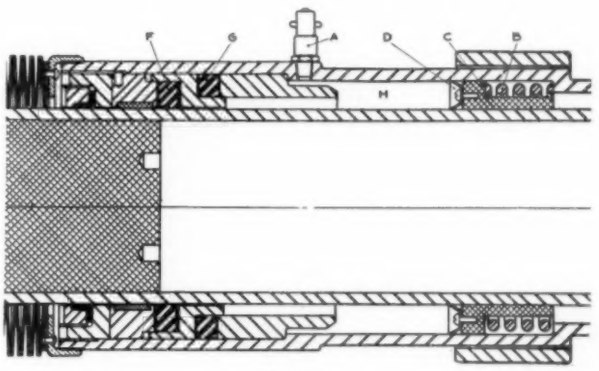


Figure 4.

In order to prevent absorption of grease by the rubber rings, and so prevent an increase in friction, the packing was completely encased in tin foil, it being of two thicknesses at moving contact surfaces and of one thickness between surfaces where there was no motion. Observation would indicate that this device will prove successful, but positive tests have not been completed at this date.

During the test of the equilibrators of which cross sections are shown in Fig. 1, it became necessary to design other equilibrators for the 4.7 inch Gun Carriage, M1921E, which is now under construction at Rock Island Arsenal. As a result of the tests upon the first assembly certain improvements were made in equilibrator design, which were incorporated in these new equilibrators, as illustrated by Fig. 4. The elaborate grease valve was replaced by a double check Alemite fitting as shown at A. It is noted that the curves on Fig. 3 are comparatively flat and do not slope as expected, to conform to the calculated curve X. The flatness of these curves was attributed to the fact that high pressure nitrogen was trapped in the grease chamber E, Fig. 1, and so kept the packing under maximum pressure throughout the test. In order to correct this (Fig. 4), a spring B was placed behind the antifriction metal ring C, which supports the silver ring D, in order that any high pressure nitrogen trapped in the grease chamber H would compress the light spring B and so keep the grease pressure in the chamber H practically the same as the nitrogen pressure.

In order to eliminate the constant friction due to the packing spring as illustrated by the curve Y on Fig. 3, the annulus of the packing F shown on Fig. 4, which is subject to the nitrogen pressure, was adjusted to obtain proper pressure between this packing and the plunger, in order that the packing friction might be dependent upon the nitrogen pressure only rather than packing spring pressure plus the nitrogen pressure. In view of the fact that the rubber ring F is encased in tin foil, the leather ring O, shown in Fig. 2, was omitted in this assembly.

Curves representing tests made on the assembly in Fig. 4 are shown in Fig. 5. X represents the calculated friction, the initial nitrogen pressure decreasing from 600 lbs. per sq. in. in the collapsed position to approximately 400 lbs. per sq. in. in extended position. Curve A represents the friction of equilibrator No. 7 upon its first assembly. The corners of the rubber rings G and F were beveled to receive

the tin foil casing and the silver cup rings. During assembly it was noted that such bevels did not provide sufficient room for these parts; therefore, these rubbers were cut to the shape of the cup rings, proper allowance being made for the thickness of the tin foil casing, after which the friction curve B was obtained by test, which it is noted

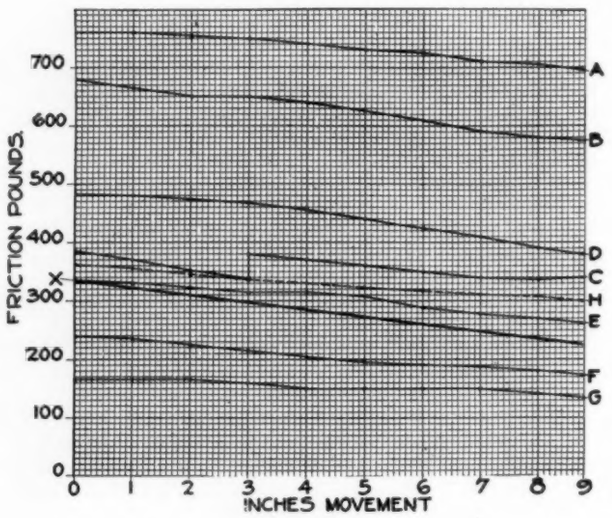


Figure 5.

is considerably less than the curve A. Indications in all tests seem to point to the silver rings as causing a large amount of friction in every case. The inside diameter of the silver cup rings inclosing the packing F was enlarged .01 inch over the diameter of the plunger, and the friction curve C obtained. It is noted that this curve is a marked improvement over both curves A and B, and the jog noted in curve C is attributed to the scratching of the surface of the plunger by the upper end of the spring B. The tendency of the spring B to leave its seat and scratch the plunger, was corrected, and no trouble of this sort has been encountered in later tests. This scratch necessitated repolishing of the plunger of equilibrator No. 7; therefore, tests were resumed with equilibrator No. 8.

As the enlarging of the inside diameter of the silver rings showed such a marked improvement, the rubber filler F was cut to its bearing width and thin antifriction metal rings placed at either side to take the place of the silver cup rings, this simple shape of the rubber filler permitting the tin foil casing to be assembled more easily. The inside diameters of the thin antifriction metal rings at either side of the filler were made .01 inch larger than the plunger diameter, and friction test made as indicated by curve D. Upon disassembly it was found that the tin foil had a tendency to creep between the inside of the antifriction metal rings and the plunger.

In order to prevent creeping of the tin foil casing between the antifriction metal rings and the plunger, three grooves were cut upon the sides of the antifriction metal rings which were in contact with the tin foil encased rubber fillers, which served to lock the tin foil in place. The inside diameter of these rings was approximately .002 inch larger than the diameter of the plunger. A friction test was then made as indicated by the curve E. It is seen that this curve shows a marked improvement and almost coincides with the calculated friction curve X.

It was thought that by replacing packing F with one silver cup ring, such a ring might be sufficient for use as a packing; therefore, such a change was made in the assembly, and a friction test run as indicated by curve F. It is seen that this change made a marked improvement in the friction and there was no grease nor nitrogen leakage.

In view of these facts, all rubber fillers were removed from the assembly and an all metal design made as illustrated in Fig. 6, except that the upper antifriction metal ring was made as shown in Fig. 4 (Ring C). Two sloping surfaces were turned upon the ring A to fit similar surfaces in the lead ring B in order to make the outer seal. The lead washer C was placed as a seal in front of the silver ring D. This assembly was then gymnasticated 15,000 times and friction curve obtained as shown by curve G, which represents the friction after 5,000 and 10,000 gymnastications. It is seen that this curve indicates a very low friction. These tests were made immediately after gymnastication, when the equilibrator was warm. After 15,000 gymnastications another friction test curve was taken as shown by curve H. The assembly was cold during this test, and it is seen that the friction has increased. This increase in friction is attributed to the fact that the coefficient of expansion of steel and silver vary in such fashion that upon cooling the silver ring tends to bind on the plunger, the same condition existing between the antifriction metal ring C, as shown on Fig. 4, and the plunger. The coefficient of expansion of tempered steel for one degree F., as given by Kent, is .00000689, and for silver it is .00001079; also the coefficient of expansion of tin is .00001163, the antifriction metal being largely composed of tin.

In order to prevent binding between the upper antifriction metal ring and the plunger, due to change in temperature, this upper ring was made of steel as shown by ring E in Fig. 6, having two antifriction metal rings F wedged therein, it being expected that steel will carry the softer antifriction metal with it as it expands or contracts owing to variations in temperature.

In order to investigate the effect of changes of temperature upon these equilibrator assemblies, hot and cold tests are being made upon them as follows: The moving parts are clamped so as to contain a certain volume of nitrogen, and loaded to a certain pressure, and the temperature taken at this pressure. The loaded assembly is then placed in a refrigerating plant and then tested when cold, the gauge reading of the pressure during test indicating the temperature of the test. The hot test is made by placing the assembly in a furnace instead of the refrigerating plant, after which it is tested, the temperature at which the test is run being indicated by the gauge pressure during test, as be-

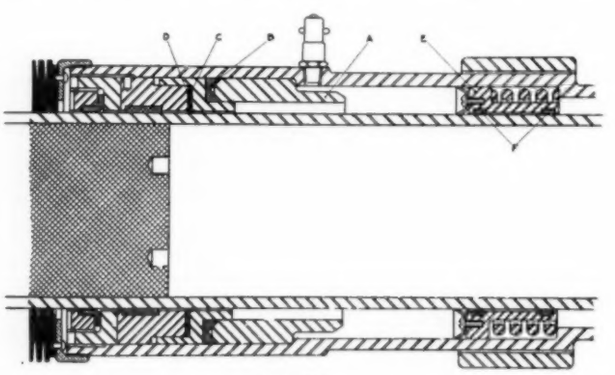


Figure 6.

fore. Such hot and cold tests are being made with a solid antifriction metal ring such as shown by C in Fig. 4, and also with the steel upper ring containing wedged-shaped antifriction metal rings as shown by ring E and antifriction metal rings F in Fig. 6. It has been noted that the co-

(*Continued on page 207.*)

Explosives from the Air

A Survey of the Sources of Explosives Supply

By

TENNEY L. DAVIS

Member A. O. A.

THE English statesman, Disraeli, is reported to have said that the civilization of a nation can be estimated by its consumption of sulphuric acid, and the propriety of his judgment is indicated by the fact that sulphuric acid is needed for nearly all modern manufacturing operations, for steel rails and copper wire, for paints and dyestuffs, for paper and ink, for all of the things by which civilization is spread and recorded. An eminent geologist in a recent lecture on evolution described how mankind has passed through the Stone Age, the Bronze Age, the Iron Age, and lives at present in the Nitrogen Age. Combined nitrogen is fundamental for the explosives industry but fundamental also for the preparation of fertilizer. It is used for preparing dyestuffs, and perfumes, and synthetic medicines, the amenities of culture. From the fertilizer combined nitrogen becomes food for us, and combined nitrogen is the gray matter with which we think. Truly the civilization of a nation can be measured by its consumption of nitrogen.

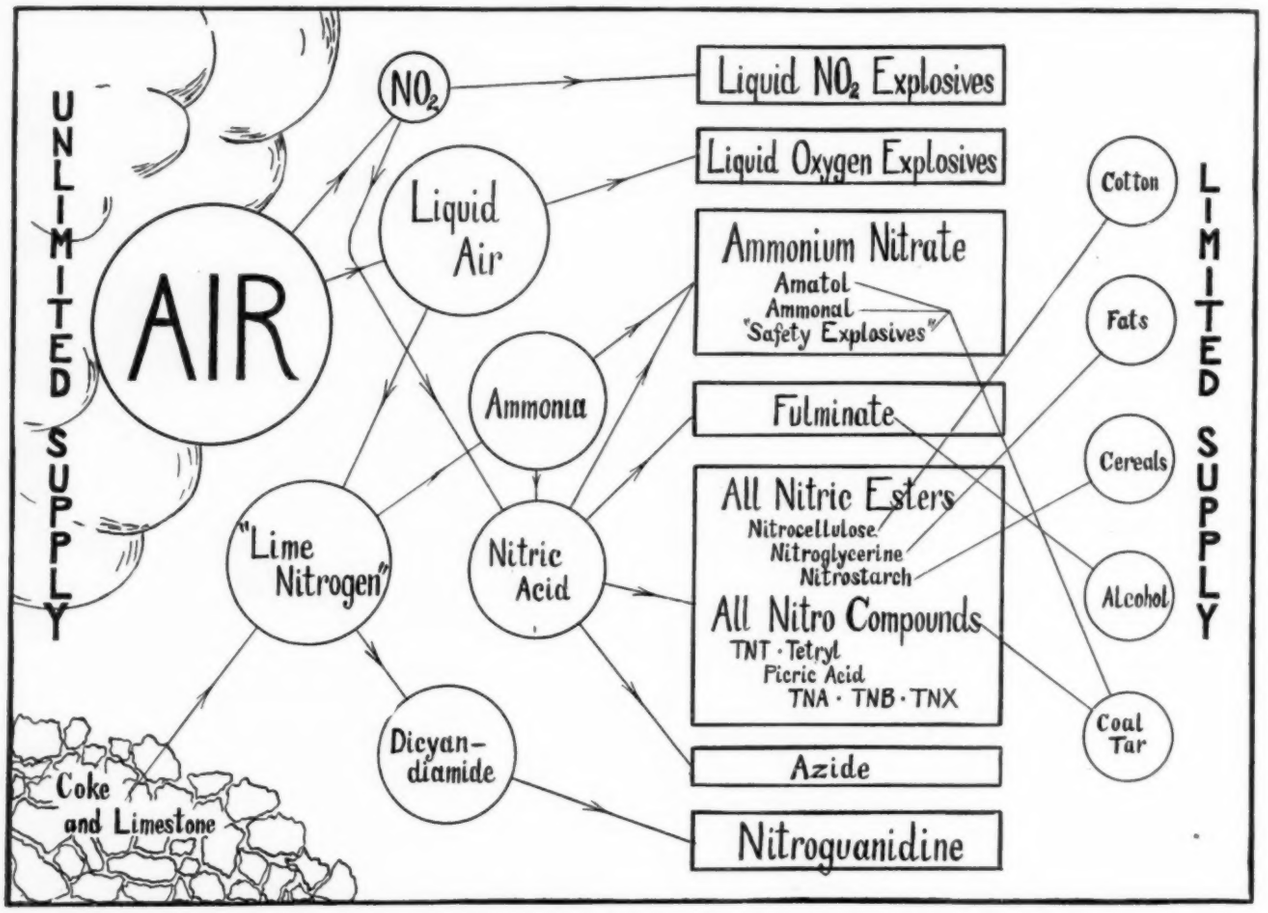
The French name for nitrogen, *azote,* and the German, *Stickstoff,* both tell that it is a lifeless and unreactive substance, the accumulated evidence of centuries, for mankind for long has been contented with the nitrogen which Nature has put into combination and delivered for his use. Things have changed in the present Nitrogen Age. We go into the air for our nitrogen and convert it, through nitric acid and ammonia, into fertilizers and explosives and a variety of other things which serve the purpose of our culture. While the military preparedness of a nation is entirely dependent on its supply of combined nitrogen, the independent culture of a nation may also be accurately gauged by the extent to which it uses the unlimited chemicals of the air.

When the Germans besieged Paris in the Franco-Prussian War, the supply of gunpowder within the walls of the city ran low and the people called upon their men of science to provide more niter. They found it, and the results were the classical researches of Berthelot and the inauguration of the Commission des Poudres et Salpetres which has continued to produce valuable research ever since. The besieged Parisians were forced literally to search their own manure heaps for saltpeter—and the supply of what they found was limited. To a people equipped to fix atmospheric nitrogen, a siege or blockade means nothing in so far as a fear of lack of nitrates is concerned. But our military explosives require also other materials for their preparation, foodstuffs, cotton, and coal tar—materials which must not be wasted and which sometimes cannot be had. With the rise of the fixed nitrogen industry, new ways of making old explosives have been developed and a new interest has attached to explosives which can be made without foodstuffs or coal tar.

When air is passed through the electric arc, the oxygen and nitrogen which it contains combine with one another to form nitrogen oxide. If the air containing this gas is now passed into water, nitric acid is produced. In countries where water power is abundant and electricity is cheap, in Sweden and Norway particularly, the Arc Process for the fixation of atmospheric nitrogen is preferred. The dilute nitric acid is neutralized with lime and the resulting "Swedish saltpeter" is used in fertilizer or converted into concentrated nitric acid for the manufacture of explosives and other materials.

Nitrogen dioxide is an easily liquified gas (boiling point 21.6°C.) and a vigorous oxidizing agent. When the reddish orange liquid is mixed with a combustible substance the resulting mixture is a powerful high explosive capable of being detonated by shock or by fulminate. Liquid mixtures, such as the mixture of nitrogen dioxide with carbon disulphide or with gasoline, have been used under the general name of *Anilites.* They are powerful enough and are suited to many of the purposes of peace, but their sensitivity to shock makes them unfit for military use. If loaded into shells, the concussion of the discharge of the gun may cause them to explode in the barrel—with the resulting destruction of the gun and the possible loss of life. If a ready-mixed anilite is used in an aeroplane drop bomb, the bomb is likely to be exploded by the impact of a rifle bullet. During the War the French aviators used a bomb in which the liquid nitrogen dioxide and the carbon disulphide or gasoline were contained in separate compartments. While the bomb was attached to the aeroplane, it carried no explosive and offered no danger. After its release, the propeller on its nose actuated a valve in its interior which caused the liquid to mix—and the bomb in flight contained an explosive. The bomb exploded on impact, the anilite being so sensitive that no detonator was needed. "Instantaneous bombs" of this sort have a limited sphere of usefulness, but are almost worthless where the destruction of property is desired. The best bombs are equipped with a relay and detonator in order that they may not explode until after they have penetrated. It has not been possible to load such bombs with liquid NO_2 explosives.

Just as combustible substances which burn in the air burn more rapidly in an atmosphere of oxygen, so, if they are mixed with liquid air, in which the oxygen is many times more concentrated than in the atmosphere, they burn with explosive violence. A porous cylinder of compressed charcoal, which has been dipped into liquid air and impregnated with it, is a powerful high explosive and may be fired with a blasting cap in the same manner as dynamite. Such an explosive has the advantage that it ceases to be an explosive after half an hour or so, for the liquid air evaporates away. If a charge has failed to fire, it may safely be left in position without fear that a workman will explode it next day with the blow of a pick. The explosive has the disadvantage that it requires to be made up at the place where it is to be used, and that liquid air cannot conveniently be carried far or



kept for long. To be sure, liquid air is a mixture of liquid oxygen with liquid nitrogen, and the liquid nitrogen evaporates more rapidly than the oxygen. The longer it is kept, the better the liquid air becomes—if it doesn't evaporate away altogether. During the War the Germans were hard pressed for explosives, and their Engineers resorted to liquid oxygen explosives, for these could be used in mining operations. Small liquid air plants were made movable on motor trucks. The liquid air itself was kept and transported in "bronze thermos bottles"—one bronze can sealed into the neck of a larger one and an evacuated space between the two. When compressed porous cylinders of wood pulp or of charcoal had been dipped into the liquid air, they could be used in the same way as dynamite, provided they were used at once. The rapid combustion of the carbonaceous material produced gas and heat and the effects of an explosion. More liquid air would be present in the explosive than would be needed for the actual combustion; this excess would be promptly converted to gas by the sudden heat and would add to the violence of the explosion. From the theoretical point of view the liquid oxygen explosive which is made from a cylinder of porous aluminum is perhaps most interesting. The combustion produces aluminum oxide, a solid; and the sudden heat converts the excess of liquid oxygen into gas which causes the effect of the explosion. This explosive may be used in a confined space without vitiating the atmosphere.

By the distillation of liquid air, pure oxygen and pure nitrogen are obtained, and the pure nitrogen is the raw material for the fixation processes which lead to ammonia. In the Haber process nitrogen and hydrogen (from the interaction of producer gas and steam or from the action of steam on red hot iron) are passed over a suitable catalyst where they combine with one another to form ammonia. In the cyanamide process the nitrogen is passed over hot calcium carbide (from coke and limestone in the electric furnace) and combines with it to form calcium cyanamide or "limenitrogen," which is of use directly as a fertilizer, which yields ammonia on treatment with steam, and which under other treatment yields other substances of importance to the explosives industry.

While ammonia is not what we ordinarily regard as a combustible substance, if it is mixed with air and passed over finely divided platinum or some other suitable catalyst, it burns and forms nitric acid. Nitric acid and ammonia combine to form ammonium nitrate, the basis of the military explosives *amatol* and *ammonal* which are used in shells and of the commercial "safety explosives" which are used in gaseous mines or are preferred because they are less sensitive to shock and easier to handle than old-fashioned nitroglycerine dynamite. Nitric acid is used for the preparation of all nitric esters and nitro compounds, for the nitration of cotton to produce guncotton, pyrocellulose, and smokeless powder, for the nitration of glycerine (from fats) to produce nitroglycerine, of starch to produce nitro starch, and of substances from coal tar to produce trinitrotoluene, trinitroxylene, picric acid, tetryl, tetranitroaniline and our other military high explosives. It is judged that it is unnecessary to dilate on the importance of these substances. For the preparation of ammonia by the cyanamide process, and thence of nitric acid and of ammonium nitrate, the electric current is needed; the only

other raw materials are coke and limestone and the atmosphere.

When metallic mercury is dissolved in nitric acid and the solution is added to alcohol, a vigorous reaction sets in and crystals of mercury fulminate presently precipitate. It is the standard material for detonators and blasting caps. Lead azide which recently has found use for similar purposes, especially in "re-enforced detonators" is also prepared from atmospheric nitrogen. When nitrous oxide or "laughing gas," prepared by the careful heating of ammonium nitrate, is passed over hot sodamide, prepared by the action of metallic sodium on ammonia, sodium azide is produced. This salt fortunately is not very sensitive to heat or to shock. If it is dissolved in water and treated with a soluble lead salt, the desired lead azide is precipitated.

Another explosive which can be prepared from atmospheric nitrogen is the *nitrourea* or *nitrocarbamide* which is now being studied in various countries. It may or may not prove to be suited to military uses, but, in the meantime, it is in any case another item to add to the list of explosives obtainable from the air. Urea itself is a colorless crystalline substance, soluble in water, used directly in fertilizer and employed extensively in the manufacture of celluloid, pyroxiline, and artificial ivory. It may be prepared by the action of sulphuric acid on lime-nitrogen under suitable conditions of concentration and temperature. It may be prepared more directly and cheaply by the interaction under pressure of ammonia and carbon dioxide (from the heating of limestone). Urea combines with nitric acid to form a crystalline nitrate which may be dehydrated by concentrated sulphuric acid to produce nitrourea. It is reported that nitrourea and its metal derivatives are "brisant explosives highly resistant to blows and shocks."

Most interesting of all the explosives which can be prepared from air is *nitroguanidine,* and it is unique because it cannot be prepared conveniently from any other source. It is but slightly sensitive to shock and as a high explosive it is about as powerful as trinitrotoluene. A German Minenwerfer bomb taken in August, 1916, was found to contain an explosive which consisted of 50 per cent nitroguanidine, 30 per cent ammonium nitrate, and 20 per cent paraffine, a cheap and powerful explosive not readily detonated by shock. Nitroguanidine further has the remarkable property of being cool. If exploded by itself, it produces no visible flash. If incorporated into nitrocellulose powder, it renders it flashless without impairing the ballistics—and naturally reduces erosion and lengthens the accuracy life of the gun.

In 1901 Vieille published his classical researches on the phenomena of erosions (Memorial des Poudres, II, 157). By determining the temperature and force of various explosives and by exploding them in a bomb so constructed that the gases escaped through a small hole in a weighed steel die and swept away weighable amounts of the metal, he was able to get an insight into the properties of the explosive substance which determined its erosive effect. During the course of his investigations he found that nitrocellose powder in which nitroguanidine has been incorporated produces a flashless discharge. The data in the following table, taken from Vieille's original article, page 195, speak sufficiently for the power and coolness of nitroguanidine.

	Charge	*Pressure*	*Erosion*	*Erosion per gram*	*Force*	*Temperature*
Military Smokeless B. F.	3.55	2253	25.5	7.19	9600	2676°
Black Sporting Powder	8.88	1958	40.0	4.5	3000	3530°
Gelatine Dynatime	3.35	2458	105.0	31.4	10000	3545°
75 per cent Dynamite	3.35	2084	60.3	18.0	8000	3161°
Nitromannite	3.54	2361	83.5	23.6	10000	3429°
Nitroguanidine	3.90	2019	8.8	2.3	9000	907°

Flashless nitroguanidine powder was early prepared at Picatinny Arsenal, but the cost of the nitroguanidine (about five dollars a pound) was so great that the powder had only an experimental interest.

The first nitroguanidine was prepared from guanidine thiocyanate by direct nitration or by conversion first to some other salt of guanidine which was later transformed to the nitro derivative. Its preparation was difficult, and it invariably contained traces of sulphur compounds which impaired the stability of the nitrocellulose with which it was mixed and caused the powder to blister. When the cyanamide process for the fixation of nitrogen came into large scale use, a source of guanidine which had formerly been inaccessible and a chemical curiosity became suddenly cheap and abundant.

When lime-nitrogen is extracted with water and the solution is evaporated, crystals of dicyandiamide are deposited. This substance is cyano-guanidine and, treated with sulphuric acid at suitable concentration and temperature, yields guanidine, or more properly guanidine sulphate, which can be nitrated to nitroguanidine free from sulphur and suitable for use in smokeless powder. The theoretical yield from this process is one molecule of nitroguanidine from one of dicyandiamide. We have recently discovered that dicyandiamide heated with ammonium nitrate yields *two* molecules of guanidine nitrate. If this latter substance is dissolved in concentrated sulphuric acid and the solution is diluted with water, nitroguanidine precipitates out, *two* molecules from *one* of dicyandiamide. No nitric acid is needed, no carefully regulated nitration, and nitroguanidine may be prepared from coke, limestone, and the atmosphere, and sulphuric acid—and the sulphuric acid is not consumed, but may be recovered if desired by the evaporation of the mother-liquors.

One other explosive deserves to be mentioned, *nitrosoguanidine,* remarkable because its properties render it entirely unfit for any practical use at the present time. It may be obtained from nitroguanidine by the carefully regulated action of zinc and acid. It is a "primary explosive," that is, it explodes from fire or from shock, but it is lacking in brisance, for its molecule contains no heavy atoms. Its explosion produces much gas, but the gas is cool. A small heap of the material placed in the open palm of the hand may be exploded by a match, but the explosion produces no visible flash or perceptible sensation of shock or of heat.

The foregoing discussion has made reference, specifically or by implication, to all explosives of practical importance for military or commercial purposes—except the chlorates and perchlorates. These are made by the electrolysis of brine solutions, from a source of supply about which we need not worry. But if we wish ammonium chlorate or perchlorate, we must also have ammonia. This is supplied by Nature in limited quantity or is produced from the air in any desired amount by chemical plants equipped for the fixation of nitrogen.

The ability of a nation to maintain itself independently in a military way is dependent upon its supply of combined nitrogen. Nature provides a limited supply, but an enemy's blockade can often shut off much of it. Nature, however, offers us an unlimited supply of uncombined nitrogen which we are at liberty to fix for our purpose. And it is an ancient truism that the man or the nation lives best which takes the most advantage of the things which Nature provides. The nation is best prepared which takes the most advantage of the powers of the air. It was a wise saying of Lord Northcliffe that "the best propaganda is the truth."

Ordnance Problems of the Past

By

C. H. GODDARD

Member A. O. A.

THE close of the recent war left producers of ordnance matériel with a very considerable problem before them—that of accomplishing the transition from war-time to peace-time production with as little disruption of policies and practices as would be compatible with the magnitude of the situation. This transition has, as we know, been safely and expeditiously accomplished, though many an executive must have faced it with misgivings.

But the problem of today, or rather yesterday, is as naught compared with that which faced our Ordnance forefathers in '65. They were confronted, not only with a situation parallel to that which has been recently presented to us, but with another of equal, if not greater, magnitude. For the close of the Civil War marked the end of an era in the development of small arms—that of the percussion cap. The period of the metallic cartridge was at hand. So imminent was it that percussion arms were already semi-obsolete, and naught remained save to discard them altogether (for military purposes) or to bring them, by some method yet to be devised, up to date.

Metallic cartridges meant loading by the breech. Neither idea was by any means new. Breech loaders are as old, almost, as firearms. Our beautiful bolt actions of today are merely improvements on crude products of the 15th century. Even the metallic cartridge can trace its ancestry back 400 years or more. But in those early days, the flame to ignite the powder came to it from *without*, passing through a small hole in its (iron) case. And though breech-loading systems without number appeared—and vanished—the metallic cartridge, owing to numerous serious defects, never enjoyed popularity. From time to time improvements appeared, the most important being the substitution of an elastic metal (brass) for iron in the composition of

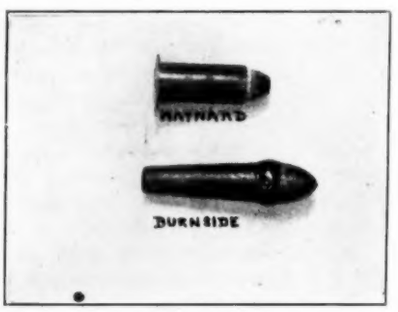


Figure 1.

the case, thus practically eliminating the age-old bogey of the breech loader—escape of gas to the rear.

But the last productions along this line, as exemplified by the Maynard and Burnside cartridges (illustrated in Fig. 1), still retained the fatal defect of depending upon flame from an external source for ignition of the powder charge. (Each of these has a tiny aperture in the center of its base through which the flame from a percussion cap reaches the powder within.) Ammunition of this type was a distinct improvement over the linen and paper cartridges then common, and still satisfied those conservatives who held that it was dangerous to incorporate both primer and propelling charge within the same casing. This idea, ridiculous as it may seem today, was widely held, and even as late as 1866, Gen. William H. Morris, U. S. A., stated in a lecture before the Royal United Service Institution that

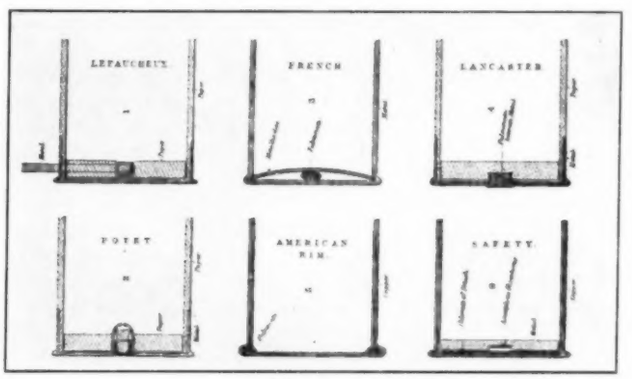


Figure 2.

"for army purposes the balance of opinion would seem to be in favor of keeping the fulminate separate from the cartridge, in order to diminish the liability to accidents."

The "balance of opinion" to which he refers, must have existed mainly in his own imagination. As a matter of fact, the infinite superiority of metallic ammunition containing within a single case, powder, ball, and primer, was generally recognized. Introduced in pin-fire form by Houiller of Paris in 1847, rim and central-fire types soon followed from the same author, and the three were already in wide use. The accompanying cut (Fig. 2*) shows the six forms of metallic ammunition then prevailing (1866). Of these, all but the non-reloading central fire types remain, with minor modifications, in use today, showing that there have been no advances in fundamental design in nearly sixty years.

The United States, staggering under its Civil War debt, cast about for a means to adapt its stock of rifles on hand to ammunition of the new type rather than undertake complete replacement at tremendous cost. The method of alteration proposed by E. S. Allin, master armorer at Springfield Arsenal, was accepted from among quite a number submitted, and work begun upon the transformation of the .58 caliber muzzle loading rifles turned in at the end of the war. Allin's original system (1865) did not prove overly satisfactory in service, and it was modified and improved in 1866, 1868, and 1870. Along with the changes in the breech mechanism came a reduction in caliber from

*Reprinted from the *Journal of the Royal United Service Institution*, Vol. X, 1867.

.58 to .50. This was accomplished first by relining the barrels on hand, and later by the fabrication of new barrels of .50 caliber. Fig. 3 shows the percussion model of 1864* (the last of the regulation muzzle-loaders) and the standard

Figure 3.

conversion type of 1866. The model of 1868 was the first to give really satisfactory service. A cut of the breech system of this arm appears in Fig. 4.

The Model 1868 made good. The transition from cap to cartridge, muzzle loading to breech loading, had, so far as shoulder arms were concerned, become a reality.

The rifle question settled, that of the revolver remained. As in the case of rifles, the government's purchases had been divided among a number of concerns, but while muzzle loading rifles had been standardized during the latter years of the war, along a single pattern, no such policy had been adopted with reference to the smaller arm. It would have been folly to attempt conversion of all revolver types, so but two were seriously considered, Colt and Remington, these having been purchased in the largest numbers. Samples were altered both at Springfield Armory and by the parent factories. Other makers undertook to transform their own products. A number of conversion systems were devised, these finally simmering down to two general types. Remington found both useful, while Colt concentrated on one.

In the first, a breech plate of varying thickness is interposed between the rear of the cylinder and the frame. In

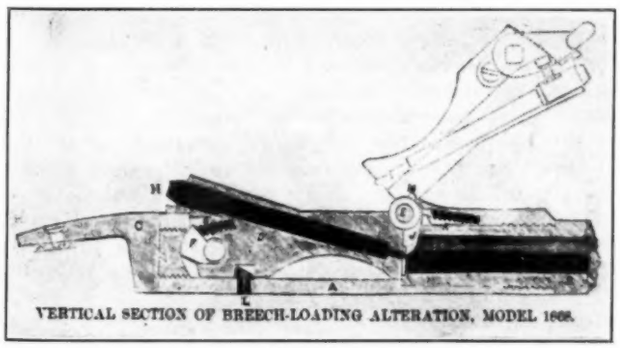


Figure 4.

some instances an entirely new cylinder is supplied. In others the original is retained. The depression on the right side of the frame, for capping, is deepened to permit cartridge insertion without removal of the cylinder. Those types with very thin breech plates are without loading gates (see Fig. 5 showing Remington .44, in pre- and post-conversion types). By increasing the thickness of the breech plate in the Remington, anchorage for a loading gate was secured.

The common Colt method of transformation permitted the retention of the original cylinder, a portion of which was cut away at the rear, the gap being filled by a thick breech plate to which loading gates were, or were not, attached according to the model. Ejectors were sometimes furnished, sometimes not. Ordinarily, no arm with barrel of less than 4½ inches length was fitted with ejector or gate. Military types were generally converted for central fire ammunition, pocket arms for both types (rim and central). (See Fig. 6—Colt .36, original and as converted with ejector and gate.)

The second general type of alteration provided no fixed breech plate, its place being taken by a detachable cylinder cap bearing the ratchets which the hand engages. This system was largely followed by Remington in converting their smaller (non-military) models. A pin projecting from the rear of the cylinder fits a socket drilled into the detachable cap and causes the two to rotate as one when the

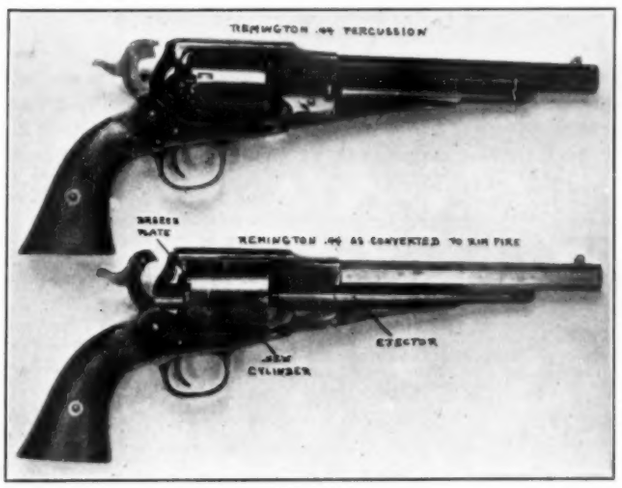


Figure 5.

hammer is cocked. Manipulation of arms of this type is of course extremely slow, as the cylinder must be removed, decapped, shells inserted, cap replaced, and arm assembled, before a shot can be fired.

Remington conversions found today are practically all on the rim fire system. Those with breech plate commonly had ejectors (see Fig. 5) while some had loading gate but others had none. Those with cylinder caps are of course without ejector or gate.

In the sporting field, some arms makers who could not devise satisfactory conversions brought out metallic cartridge models so closely resembling their powder-and-ball predecessors as readily to be taken for transformations, rather than new models. Others, afraid to cast loose so soon from long established custom, designed arms to function either with loose powder and ball, or metallic ammunition. The Williamson derringer (illustrated in Fig. 7) is an example. The steel shell supplied with it (seen just above the pistol) could be capped on the nipple at the rear, filled with powder, and placed in the chamber behind a ball or charge of shot. Or it could be removed and a rim fire cartridge inserted. The hammer and breech are so constructed as to permit function with either cap or cartridge without special adjustment. This same principle is employed in the .38 Ballard rifle. A later development of

*The specimen shown is equipped with Maynard tape primer. This was not regularly furnished on this model.

this rifle was a reversible firing-pin, permitting the use of either rim or central fire cartridge of .38 caliber in the same arm.

In this manner, the United States Army Ordnance Department and private manufacturers met a problem which

Figure 6.

eous, and percussion arms went very slowly into the discard. The army on the other hand, once the decision was made, had to effect the change as rapidly as possible, discarding at once all obsolete types. That the conversion system it chose was a good one is well evidenced by the fact that it

Figure 7.

at first threatened great financial loss, and the waste of quantities of valuable materials. In the sporting field the transition was fairly easy because universal popular acceptance of metallic cartridge types was by no means instantan-

persisted, with slight modifications, through a series of models of single shot rifles which were not displaced until the introduction of a small bore magazine arm (Krag-Jorgensen) in the early 90's.

Transport Wagons for Medium and Heavy Field Artillery

PART I.

By

T. A. CONLON

THE wagons under discussion here were designed to facilitate the movement of medium and heavy mobile artillery.

The properties of these wagons must embody ease of loading and unloading under most unfavorable conditions in a limited time.

In the case of the medium material, it is usually necessary to carry the mount in only two loads, consisting of the gun on the transport wagon and the remainder of the service mount on the gun carriage wheels; such material, however, must be capable of moving intact over short hauls. For these short hauls it is usually necessary to retract the gun and lock it to the trails some distance out of battery, thereby distributing a large part of the load on the limber.

With the heavy artillery material the number of loads depends largely on the caliber of the gun. With the British 9.2-inch howitzer, it is 3; with the French 240 millimeter howitzer it is 4; and with the German 42 centimeter howitzer it is 6. With such mounts as the above, it is necessary to move into prepared positions, and set up platforms before moving the upper structure into place.

With the design of heavy mobile artillery it is necessary to constantly keep in mind the problem of transportation, and to make such provisions as are necessary to insure ease of transportation and erection. This requires attachments on the transport wagon and mount, to make it possible to couple exactly and immovably the two together.

The types of transport wagons are as varied as the mounts that they serve. Some have the automobile type of steering mechanism, others have the fifth wheel type, some are spring supported and rubbed tired. On some the gun slides the entire length and is equipped with elevating and traversing screws to insure the accurate alignment of the gun slide in the cradle with those in the transport wagon.

French Transport Wagons for Medium and Heavy Field Artillery.

The French transport wagons shown in the illustrations are for material used in the recent war; they are usually of the Schneider Company design.

Characteristics of the Schneider gun carriage are the recoiling parts which consist of the gun and cradle.

When the gun is unlocked from the cradle it can be lifted out. The company takes advantage of this condition and builds its transport wagon to suit.

Their wagons are of a very simple construction and depend upon the load to form the unit. However, when the load is not on the axles attachments are provided to connect the front and rear axles to make up a portable unit.

Figure 1 illustrates one of the four vehicles that transport the 240 millimeter Schneider Howitzer Carriage, Model of 1918. It is rubber tired and has a modified form of fifth wheel steering mechanism, and a false trail that ex-

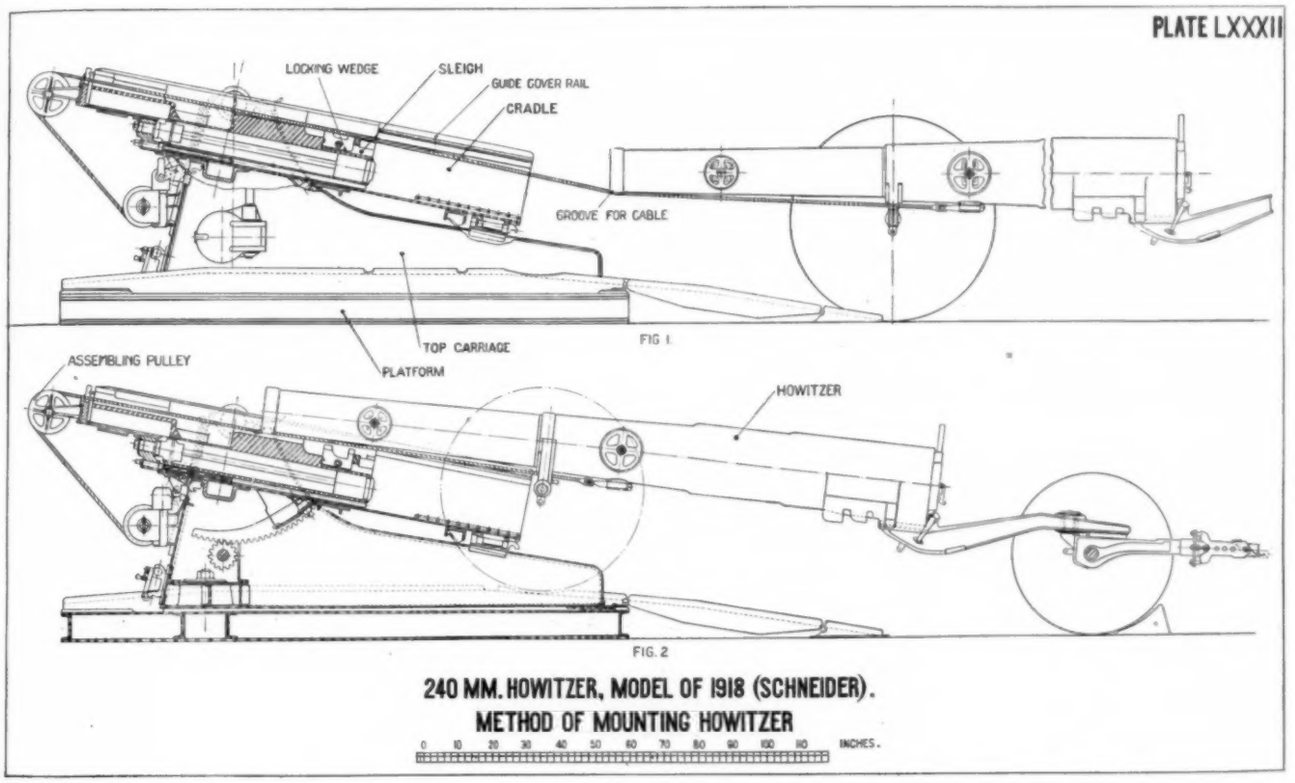


Figure 1.

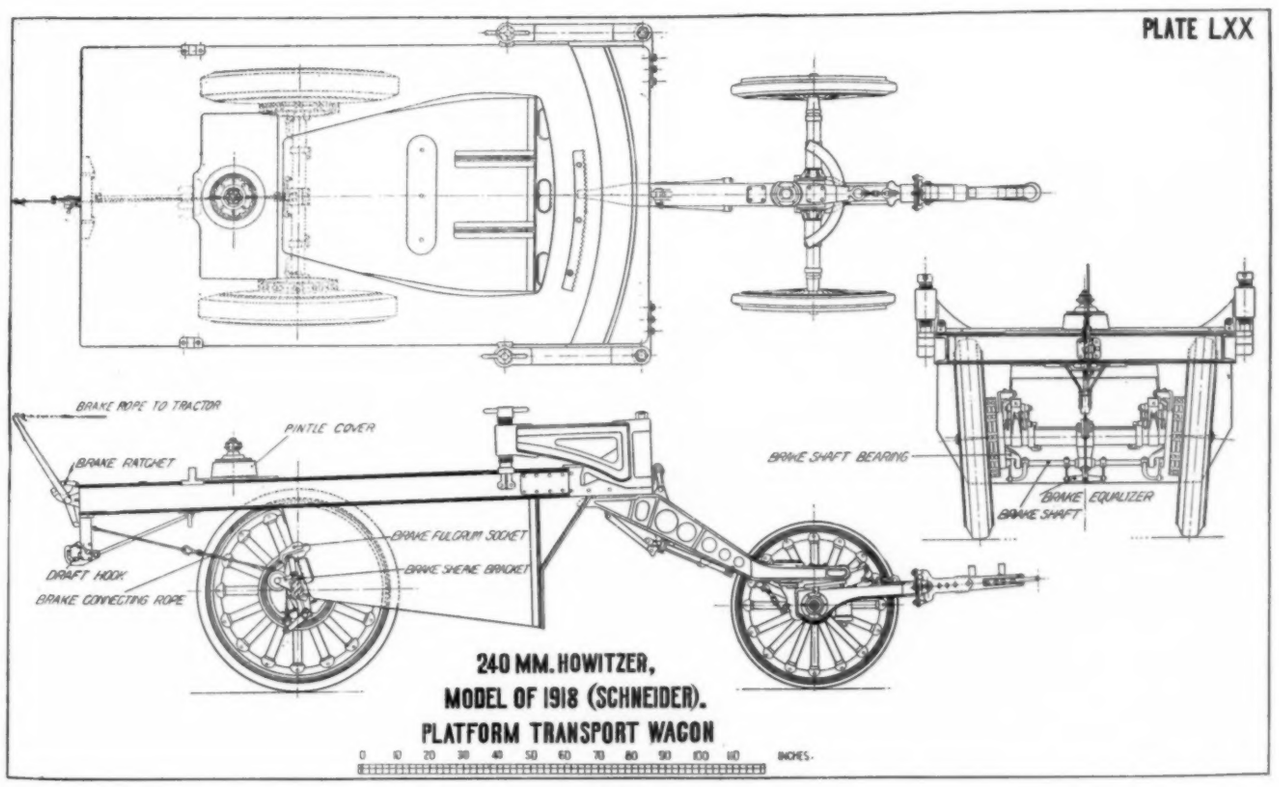


Figure 2.

tends from the front axle to engage slots in the under side of the breech. The rear axle supports a seat for the gun and brackets for the brake mechanism; the brake is applied from the tractor.

To mount the howitzer, elevate the cradle 11 degrees and ascertain that the guide rails are in place. Attach the free end of the windlass cable on the cradle to the hook on under side of the howitzer. Draw the loaded wagon for-

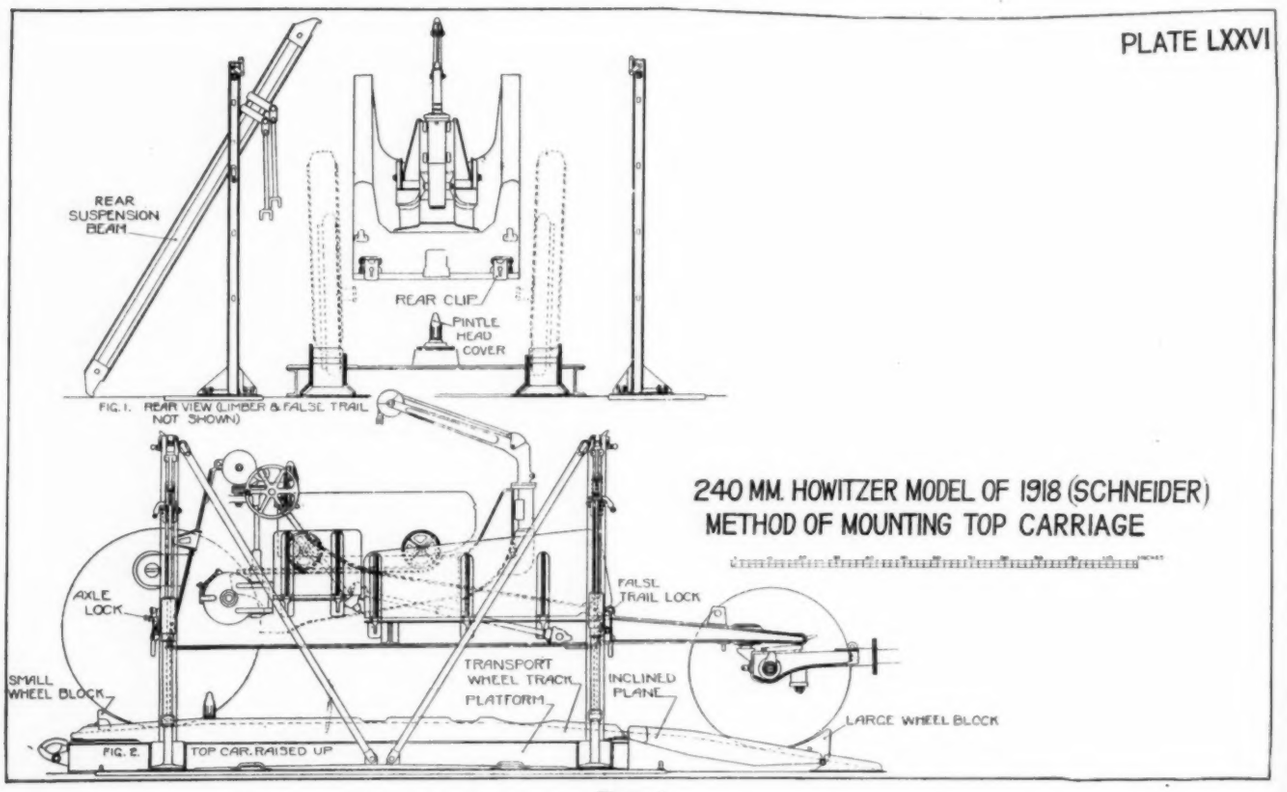


Figure 3.

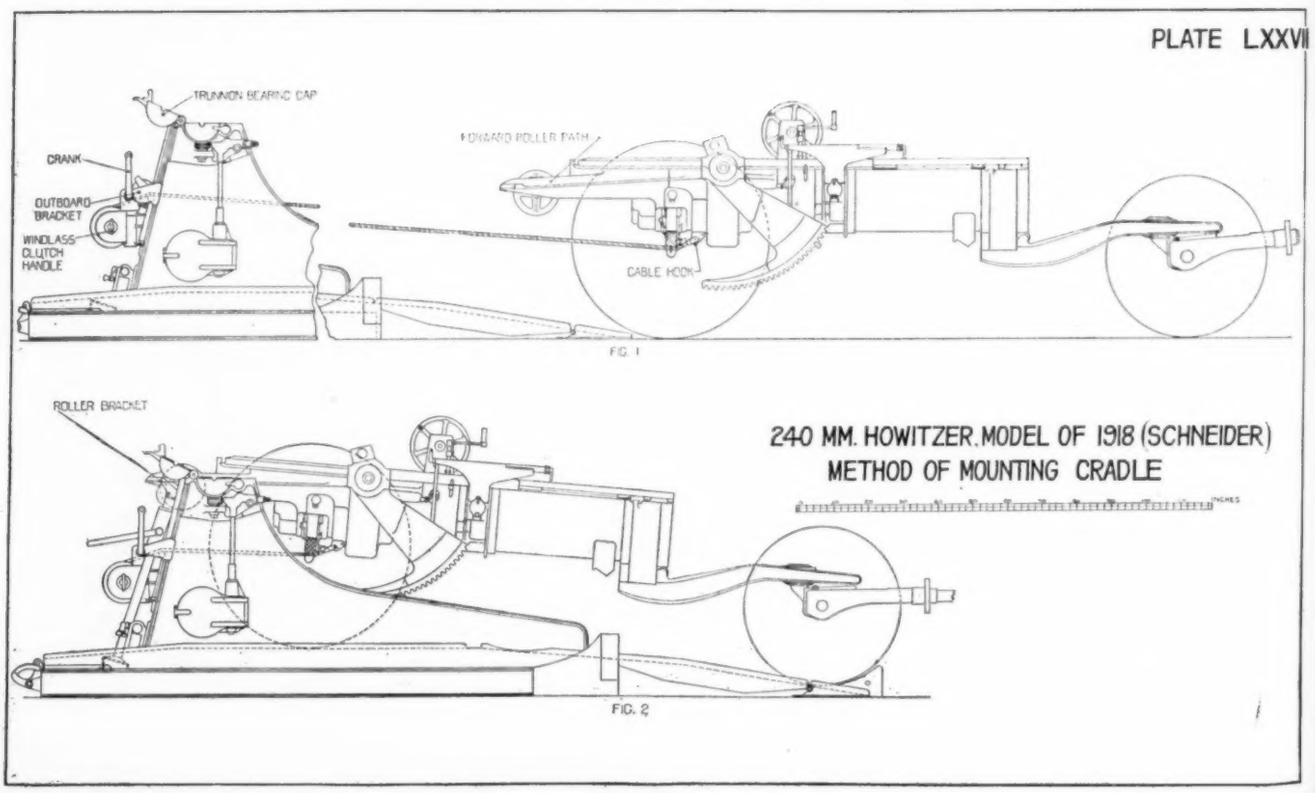


Figure 4.

ward until the rear axle reaches the end of the cradle and the rear wagon wheels are clear of the track, at the same time steering the wagon with the assistance of a pole attached to the drawbar. Remove the rear wheels and axle. Continue to draw the howitzer up until it is in the firing position. Lock the gun to the cradle and remove the false trail.

When not loaded the front and rear axles are held together by the false trail to make a portable unit.

This howitzer weighs 10,800 pounds, and the wagon loaded 15,200 pounds. The weight under rear wheels is 10,356 pounds. It would appear difficult to maneuver this load on unfavorable ground into alignment with the tracks shown on the sketch. However it is a very simple construction.

In setting up the platform illustrated in Figure 2, a piece of level ground should be selected and a hole dug for platform, using the pit templates to lay out same.

The platform transport wagon should be run over the pit and block wheels.

The erecting frame should be set up, jacks placed in position and platform raised and the limber and rear axle run out.

The transport wheel track should be removed and the platform lowered onto the ground.

The weight of wagon complete is 16,200 pounds.

The weight under rear wheels is 11,700 pounds.

The wagon illustrated in Figure 3 is unloaded with the assistance of the erecting frame used to lower the platform into place.

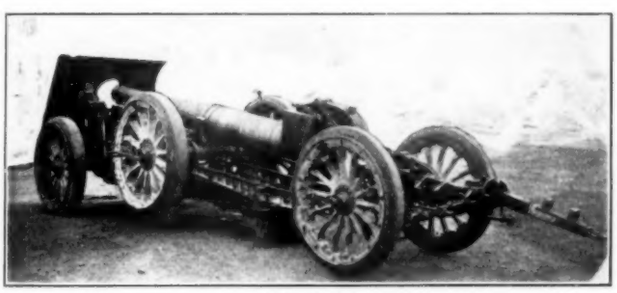


Figure 5.
155-mm. Gun Transport wagon (Schneider), Model of 1917

The weight of the wagon loaded is 12,500 pounds, 8,500 pounds of which is on the rear wheels.

To mount the cradle (Figure 4) windlass cable should be attached to hook under trunnion band, assembling pulley attached.

The cradle transport vehicle should be drawn forward by means of the windlass until the lugs on the roller brackets can engage the projections on the ends of the forward roller paths. The limber wheels should be blocked.

Two jacks (right and left hand) should be placed on the jack foot blocks with their caps under the roller brackets.

The rear wheels should be raised off the tracks by means of the jacks and the rear wheels removed from the axle.

The axle should be unlocked from the cradle, and the axle-lifting levers inserted in the holes in the axle ends and used for lifting out the axle.

The cradle should be drawn forward, at the same time raising the jacks so that the trunnions clear the top carriage. The limber wheels should be followed up with the large wheel blocks to prevent accident in case the cable should break.

The jacks should be lowered until the trunnions rest on the bearing and lock the bearing caps.

The false trail should be unlocked and the trail removed with the front limber. The rear wheels and brake mechanism should then be assembled on the rear axle and the false trail and front limber connected to it to form the cradle transport wagon close coupled.

The weight of the wagon loaded is 14,600 pounds.

Figure 5 shows the wagon in position for unloading. It

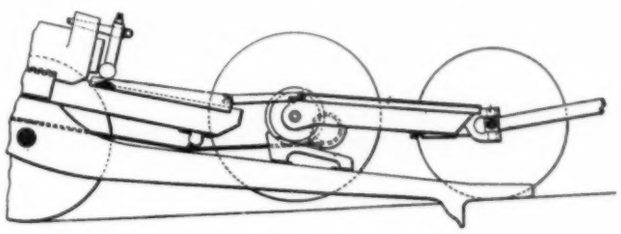


Figure 6.

is a typical Schneider design. It will be noticed that the front and rear wheels are off the ground and that the gun is in position to be drawn on the service carriage.

The weight of the gun is 8,300 pounds.

The weight of the wagon loaded is 13,400 pounds.

Figure 6 shows the short guide rail on the trail which receives the large rollers on the wagon axle. These rollers lift the rear wagon wheels off the ground. A traversing mechanism on the front axle together with the universal joint at that point permits the adjustment of the wagon to bring the gun slide into alignment. The gap between the wagon and cradle is bridged by temporary extensions. The operating handle of the retracting winch is located inside the rear carriage axle.

This location of the retracting winch does not appear necessary as it complicates things.

The gun barrel is raised by screwing down the gun rollers until they lift the gun. The retracting winch which is driven through the rear axle is connected to the gun by the cable which passes under the cradle and over a pulley on the cradle's front end.

Figure 7 illustrates a transport wagon of a Schneider design which is built for guns of the cradle recoiling type of mount such as the Schneider 155 millimeter Gun and Howitzer and the 240 Howitzer. With this type of wagon it is not apparent how a gun sliding in grooves may be dismounted as the arrangement shown requires that the forecarriage pick up the load when its seat on the gun is within reach, and then move forward with the load until the jack stand can take up its position which is under the center of gravity of the gun.

To assemble the gun on the service mount, first add the cradle extension to the mount, then put the jack in place

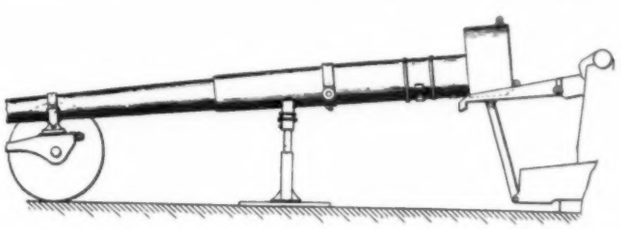


Figure 7.

and run the rear wheels out. The relation of the breech to the end of the cradle when the wagon is run up will be such that the cradle extensions will be under the breech so that the roller on the breech will engage the extensions when the jack is removed. The gun can be hauled into position until the second set of rollers engage the cradle extensions.

Just how well this wagon would operate in loading on unfavorable ground without a guide track for the wheels is not clear.

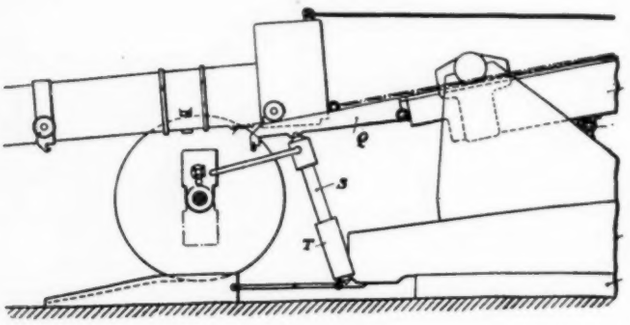


Figure 8. Transport Wagon

The jack has a pivoted seat for the gun and the gun has special recesses for the fore and rear carriage. The jack stand consists of two independent jacks to take care of irregularities in the ground.

This vehicle is similar to the previous wagon with the exception of the location of the jacks and the addition of the traversing screw in the ground ramps under the front wagon wheels which assist in lining up the wagon. If the vertical plane of the gun barrel should not coincide exactly with the vertical plane of the gun carriage, the parallelism between these planes may be first assured by causing the gun barrel to rotate slightly on its axis by means causing the gun barrel to rotate slightly on its axis by means of the mechanism carried by the rear axle. The coincidence of these planes may be finally assured by a transverse displacement of the front axle on the ramps. The wheels of the front axle rest in channels carried by nuts working on screws journalled in bearings formed on the ramps. When the gun slides are in line, the jacks S—T are operated to raise the extensions Q, and by means of the latter, to raise the rear portions of the gun barrel also; the whole then occupying the position shown in Fig. 8.

By operating the winch, the parts are brought finally into the position. At this moment the separation between the front axle and the gun may be effected, the separation between the rear axle and the gun barrel having been already effected previously in passing from the position shown in Fig. 9 into the position shown in Fig 8.

When the gun barrel has been remounted upon its carriage, the extensions Q may be removed.

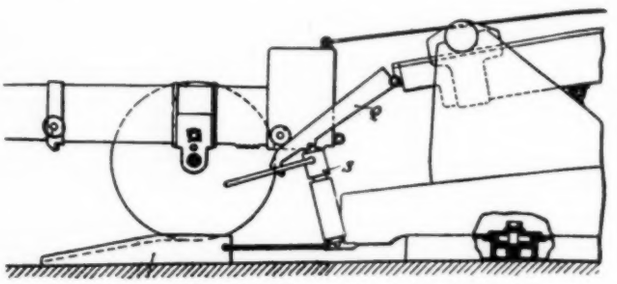


Figure 9. Transport Wagon

(Part II will appear in an early issue of ARMY ORDNANCE.)

The New Reconnaissance Tractors

By

THOMAS HAY NIXON

IN accordance with the report rendered by the Westervelt Board, two light Reconnaissance Tractors, to take the place of the mounted man, were ordered designed and constructed by the Ordnance Department. In part, the requirements set down by the Westervelt Board are as follows:

"A light weight tractor to fulfill the one incomplete detail lacking in motorization, i. e., the motorization of the individual man. This tractor would have a very low center of gravity, 40 inches wide over all, articulated tracks approximately 6 inches by 8 feet, with small body for carrying 2 men or 500 lbs., water cooled engine capable of operating under water and at all possible tipping angles, with speed ranges from a sure low reduction of 3, 8 direct-drive, 12 over-drive, miles per hour. This tractor to be designed for replacing the horse of individually mounted men, for use in reconnaissance, for pack transportation including machine and mountain guns, for transport of ammunition, laying wire, etc."

In order to fulfill the requirements of the Westervelt Board, it was determined to build two tractors, one of about 800 pounds weight and the other of about 1,600 pounds weight. In order to obtain the desired special features and not exceed the weight specified, it became necessary to turn to an alloy of small specific gravity. After considerable study duralumin, with a specific gravity of 2.8, was adopted.

The striking properties of this metal were discovered in experiments and investigations carried on from 1903 to 1911 by A. Wilm, a German scientist. Since that time his work has been supplemented by European and American scientists. Duralumin is the commercial name given to aluminum base alloys having a copper content up to approximately three-fourths of one per cent, maganese up to one per cent, and slight impurities of iron and silicon.

The outstanding property of duralumin, which makes it so very useful commercially, is that it combines great strength with a very low specific gravity. It has about the same ultimate strength as structural steel and weighs only about one-third as much. A second property which makes duralumin valuable commercially is that the metal will harden after heat treatment, but not until some time has elapsed. This permits working the metal into the desired shapes and the flattening and straightening of the pieces where necessary, before hardening begins. Due to the fact that duralumin resists corrosion, it is particularly adapted for amphibious tractors. Duralumin is a good conductor of electricity, and in wet locations is subject to the injurious effects of electrolysis unless well grounded. The strength of duralumin depends not only upon its chemical composition, but to a greater degree upon the heat treat-

ment to which it is subjected. Table I shows the results of tests carried on at Rock Island Arsenal. During the late war, duralumin was used extensively for structural purposes in connection with aviation. This brought the material before the eyes of the engineering world and today the commercial use of it is covering a wide range. At the present time there is much research in alloys of aluminum.

In order to obtain a vehicle approximating the mounted man in weight, duralumin was used throughout in the manufacture of the reconnaissance tractors. One of the most interesting features was the use of duralumin in the construction of the tractor body. Sheet duralumin riveted with duralumin rivets was used. At first considerable difficulty was experienced in the forming of the duralumin sheets in the annealed stage and afterwards applying the heat treatment to obtain the desired hardness. The sheets buckled and warped out of shape. Re-forming was necessary and proved both difficult and expensive. This was particularly true with the longer sheets. After considerable experimentation it was found that, by just forming the sheets roughly, placing them in a niter bath at a temperature of 925° F. for thirty minutes and then quenching in hot water, followed by finish forming the plates cold, very little distortion resulted. In the assembly of the body all rivet holes were reamed to the natural size of the rivets and the rivets driven cold. The rivets were used in the annealed condition, and the length of aging prior to driving apparently made no difference. The spinning process was employed. For water-proofing, tar paper was used under all joints, corners, seams and angles, while intricate corners were soldered. Lynite castings and forgings were used for those parts subjected to heavy stresses. The castings and forgings for the transmission case jackshaft housing, side frame, bed plates, levers and brackets have proven very satisfactory.

The 800-pound Reconnaissance Tractor

The 800-pound Reconnaissance Tractor, the lighter of these vehicles, which was designed to replace the mounted man, has a weight of approximately 800 pounds and is about eight feet long, four feet wide and stands about three and one-half feet high from the ground to the top of the hood cover. The tractor is amphibious and self-propelled in the water. Speeds vary between two miles per hour up to sixteen miles per hour, over a paved road, with throttle wide open. This vehicle carries a driver and one passenger.

The track suspension consists of four 27-inch wheels, which

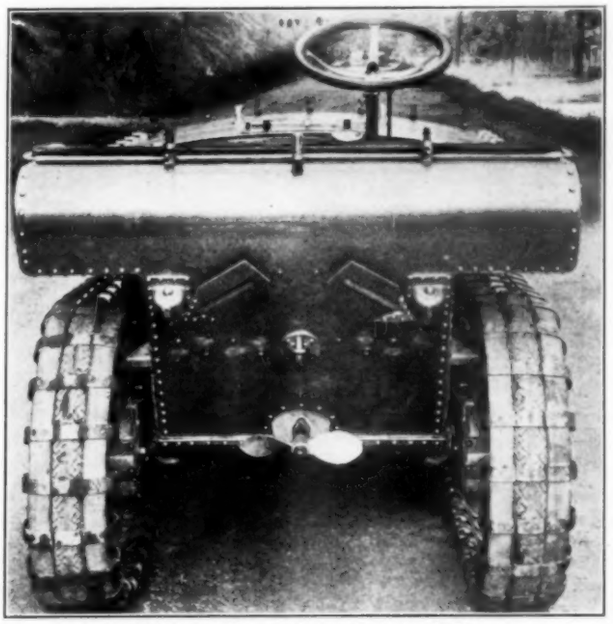


Figure 1.—Reconnaissance Tractor, 800-lb.

carry the weight, and two idlers at the front of the body.

The four weight-supporting wheels are suspended from the body, pivoted on brackets and work against helical springs. The front idler permits of horizontal adjustment for maintaining track tension, and has a helical boring to take up irregularities over rough ground. A Chase type of fabric track is used, running over pneumatic tires on the weight-carrying wheels and a solid tire on the idler. All wheels are of disc type.

TABLE I.

DURALUMIN, 7/8" ROUND.

Chemical Analysis.

Copper	Manganese	Magnesium	Iron	Silicon	Aluminum
4.03	0.52	1.67	0.54	0.27	92.97

	Ultimate Strength *Lbs. per sq.in.*	Yield Point *Lbs. per sq.in.*	Elongation *Per cent*	Reduction of area. *Per cent*	Hardness Scleroscope	Hardness Brinell
As received	32,650	16,000	16.5	43.6	27-30	57
Annealed at 625 deg. F.	32,850	16,000	19.0	42.4	20-25	50
Water quenched at 935 deg. F.	48,750	21,000	19.0	41.2	35-39	80
Brine quenched at 935 deg. F.	54,000	27,000	25.5	40.0	38-42	80
Quenched in boiling water at 935 deg. F.	52,500	26,500	25.5	42.1	40-42	80
Quenched in boiling water at 935 deg. Drawn for 1 hour at 300 deg. Aged 48 hours.	49,500	22,000	29.0	36.2	33-36	70
Quenched in boiling water at 935 deg. Drawn for 1 hour at 400 deg. Aged 48 hours.	37,500	15,000	20.0	43.9	29-32	57
Quenched in boiling water at 935 deg. Drawn for 1 hour at 500 deg. Aged 48 hours.	51,000	28,000	18.5	36.5	53-56	93
Quenched in boiling water at 935 deg. Drawn for 1 hour at 600 deg. Aged 48 hours.	32,750	10,000	23.0	47.4	24-28	52

The power plant consists of a standard four-cylinder air-cooled Henderson motorcycle engine, modified by cutting away the motorcycle transmission. The drive to the transmission is transmitted through a flexible coupling. The

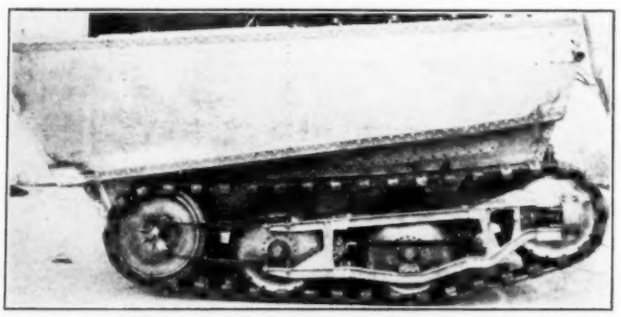


Figure 2.—Reconnaissance Tractor, 1600-lb.

transmission is of a selective type, consisting of three speeds forward and one reverse. Two additional speeds are obtained in the jackshaft, making a total of six speeds forward and two reverse. The clutch is thrown out when shifting into different speeds, by the usual foot lever. The power coming from the transmission is directed to the jackshaft, at each end of which is provided a multiple three-plate steering clutch. From these clutches a chain drive to the planetary gear units in the rear wheels is obtained. The chain mechanism is inclosed by a waterproof case.

A propeller is provided for navigating in water and is driven by a shaft directly from the jackshaft. A shifting lever is connected to the propeller shaft, which engages that shaft with a bevel gear drive in the jackshaft. When the propeller is used the track drive must be stopped by throwing out the clutch in the jackshaft. When not in use, the propeller can be drawn up close to the body. Two rudders are provided for steering, which may be folded flat against the body when not in use.

A heavy graphite oil is carried both in the chain case and the rear wheels to secure proper lubrication. The jackshaft housing is filled with light oil, which flows from there into the transmission.

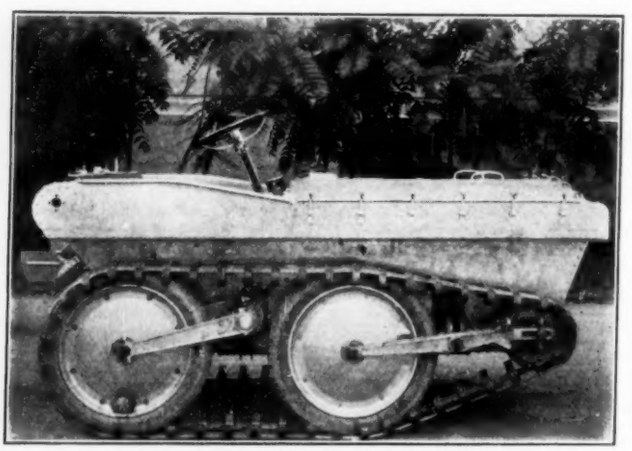


Figure 3.—Reconnaissance Tractor, 800-lb.

The gasoline is fed by a gravity system, the gasoline tank (having a capacity of eight gallons) being placed on the side and above the power plant. The average consumption over ordinary roads is about one gallon of gasoline and one pint of lubricating oil per hour.

The power plant is cooled by a small Sirocco fan held in the housing fastened to the bed plate in front of the engine. Air is drawn down through a pipe from the driver's compartment and forced through a hood covering the engine, thence down over the cylinders, and exhausts through an open vent through the cover of the engine compartment.

The steering of the tractor is accomplished through cables attached to the steering column and running back to the jackshaft, where a cam operates with the clutches which engage and disengage the drive to the track. An instrument board provides space for speedometer, hand starter for engine, choke, magneto switch and emergency brake.

The 1600-pound Reconnaissance Tractor.

The 1600-pound Reconnaissance Tractor is about ten feet long, four feet wide, and stands about four and one-half feet high from the ground to the top of the hood

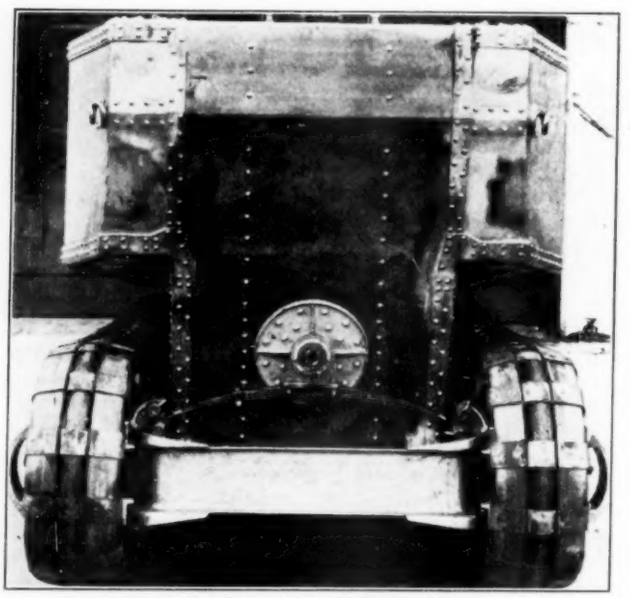


Figure 4.—Reconnaissance Tractor, 1600-lb.

cover. A driver and one passenger are carried. The tractor is amphibious and self-propelled in water. It has a range of speed from two and seven-tenths to twenty miles per hour over a paved road, with wide open throttle.

The track suspension consists of a side frame unit, from which the body is suspended on a three-point suspension. The side frames are connected in the front by a crosspiece, upon which is a bracket holding the trunnion fastened to the front end of the body. In the rear the tractor body is suspended by shackles on the rear axle to the quarter-elliptical cantilever springs fastened in the end of the side frame. The front wheels permit of adjustment to maintain track tension and work against helical springs to take up irregularities over rough ground. The weight is carried by the four middle wheels, the first pair of which is suspended from the track frame by semi-elliptical springs, and the second pair fastened rigidly to the frame. The driving wheels are held on an axle fastened rigidly to the body. The wheels are of disc type and 20 inches in diameter; the front three pairs have solid rubber tires, and the driving wheels having bronze tires with bosses which engage the track links of the Chase type fabric track with which the tractor is equipped.

The power plant consists of a standard four-cylinder air-cooled Franklin engine, 3¼-inch bore by 4-inch stroke,

(*Continued on page 207.*)

Armament Cost System

Panama Canal Department

By

DAVID H. WHITTIER

THE only reason for ever instituting a cost system in any organization is that it will increase the efficiency of the organization. In the Ordnance organization of the Panama Canal Department there are three factors which enter into its efficiency: men, money and materials. To have efficiency the men must be capable and filled with the desire to excel; the money must be plentiful enough to meet all needs; and the materials required must be on hand in proper quantity and quality.

In line with these needs, our cost system should keep before all a continuous record of their performance; a constant comparison of their work with that of others. With the knowledge that the work is being closely watched and that every good achievement is appreciated, comes the desire to excel. This desire to excel is one of the main factors in the making of capability and happiness. Our cost system must also aid us in securing the money we need. If the providers of the money feel that they are going to get a profit from their investment, it is easy to secure the money. In our case, if we can convince the Chief of Field Service and give him the means to convince Congress that every dollar given us means fully a dollar's worth of national defense, then as long as Congress feels that national defense is a desirable national investment, we will get the money we ask for.

Also our cost system must give us the means of telling how to most cheaply procure the best materials for our needs. If our quotations show that to buy a certain part will cost us $70 and our cost system shows that to manufacture that part will cost us $25, then obviously our cost system enables us to save $45.

With these points in mind, then, our cost system was instituted. All of our expenditures are for one of the three following items: Labor, material or traveling expense.

To account for the labor, the following procedure is in force. No civilian ordnance employee is authorized to do any work except on a written order from an ordnance officer. No ordnance officer is authorized to order such work unless he has funds to cover the expense. These written orders are divided into four classes: First, Modification Work Orders, coming from the Chief of Field Service; second, Maintenance Work Orders, which are issued by the Department Ordnance Officer to cover all work necessary to preserve the matériel in its condition of original issue or as modified by proper authority; third, Overhead Work Orders which are designed to cover all costs, not chargeable to some work order, such as repairs to shop equipment, salaries of office help, etc., and fourth, all miscellaneous work orders issued by the Department Ordnance Officer to cover specific jobs for experimentation on the existing material, or assisting the line troops in developing new material, or in performing work with recompense from other departments.

These four series of work orders are each assigned letters which precede all work orders under them. Thus the modification work orders are preceded by the letters B, E, F and G; the maintenance orders by M, the overhead by O and the miscellaneous by X.

To save paper work all orders in classes B, E, F and G are issued direct to the machinists by indorsement from the Department Ordnance Officer. All orders in class M are issued as blanket orders to cover the different classes of equipment. An order is issued for the maintenance of each battery, of all plotting boards at each post, of all Lewis D.P.F.'s at each post, of all azimuth instruments, M-1910, at each post, etc. This allows the local ordnance officer to direct the maintenance of the standard equipment as he wishes without the issue of a separate order for each petty job. The work order form used is shown in Fig. 1.

HEADQUARTERS
PANAMA CANAL DEPARTMENT

OFFICE OF
THE DEPARTMENT ORDNANCE OFFICER

WORK ORDER

To:

- ☐ Resident Machinist, Fort Grant.
- ☐ Resident Machinist, Fort Randolph.
- ☐ Resident Machinist, Fort Sherman.
- ☐ Depot Machinist.

You are directed to proceed with the work as outlined below:

1. Work applies to:
2. Name of part:
3. Nature of work:
4. Special instructions:

By order of the Dept. Ordnance Officer.

No.....

.....
Armament Officer.

FIG. 1.

The resident machinist at each post submits at the end of each month a time report showing the following data for every work order in his possession; first, the work order number; second, the percentage of new parts or tools required for the job and which he has on hand; third, the percentage of completion of the job; fourth, the date the job will be started; and fifth, the allocation of all the time of every employee among these work orders.

When this report is received by the Department Ordnance Officer, the time of each hourly paid man is checked to make sure that he was paid the right amount. The time

of each monthly paid man is checked and the hourly rate figured. Then all data on the time report is posted to the cost records.

W. O. No. Period (Jan. to June) (July to Dec.)

RATES		20c.	23c.	25c.	28c.	30c.	37c.	$189.28	$206.28		Total Labor	Total Overhead	% Work	% Parts
1	Hrs.													
	Amt.													
2	Hrs.													
	Amt.													
3	Hrs.													
	Amt.													
4	Hrs.													
	Amt.													
5	Hrs.													
	Amt.													
6	Hrs.													
	Amt.													
TOTALS														

Fig. 2

These records consist of two sets of cards, one card in each set for each work order. One set of cards shows in various columns the various rates of wages paid for each month. A sample of this card is shown in Fig. 2. In each of these columns is entered the number of hours worked during that month by men getting that rate of pay on that job, also the total amount these hours represent. The labor costs are totaled in another column. The percentage of parts on hand for that job and the percentage of completion of the job are also shown each month on the card. The other set of cards show a summary on each card of one job as performed at all posts for the purpose of comparing the expense at the various posts. This card is shown in Fig. 3.

MR 81686—Panama Canal—4-28-22—500

LOCAL W. O.	FORT	MATERIAL		WORK ORDERED	COST				
		ORDERED	SHIPPED		LABOR	MATERIAL		TOTAL	PER UNIT
						LOCAL	REQ.		

Fig. 3

Accounting for material cost is very simple since every requisition for material to be bought must be approved by the department head and must have entered on it the number of the work order to which the material is to be charged. The cost of this material is then entered on the back of the card for that work order, together with the number of the invoice.

Mileage charges are handled in the same way, every mileage or expense voucher being charged to some work order.

From all of the above it may be seen that the total overhead charges on our work will be shown on the overhead work order for the department. After all the data is posted from the time reports, the department overhead is prorated among all the various jobs for the month. In this way the exact status of any job may be ascertained by reference to its card, how much work has been done on it, how much material is needed for it and what the total cost to date has been.

From the above it may be seen that any data desired may be secured from the records. We are in a position to show the Chief of Field Service exactly where every cent of the money appropriated went; what jobs it was spent on. We can show at all times exactly how much it costs us to maintain any type of gun or other material; we can show a comparison between cost of maintaining batteries in service and out of service; in brief, we can compile from our records any form of cost data we have been able to conceive of.

For information in connection with the planning of our work, charts are carried, on which are shown the schedule of work as laid out for our shops. The time allotted to each job is shown graphically in its proper place in the year. Each month the chart is revised and the entries corrected. Thus we can readily see all work we have on hand, what the larger jobs are, and when any particular job will be started or finished. For the purpose of comparison and easy reference, all maintenance work is shown on sheets, one sheet for each type of armament. On each of these sheets a curve is drawn showing for each month the expense of maintaining the average battery of that type of armament. The different posts are shown in different colors so that a glance will tell which post is doing the work most economically.

Every month another sheet is made up showing certain data. The maintenance costs of typical material at all posts are listed. Thus the cost of maintaining one 14-inch gun battery is shown at each of the three posts. On this sheet also is shown the local overhead cost for each post. In addition to this is listed all jobs done at all three posts for comparison of the cost incurred by each resident machinist. Big modifications when completed are shown in total costs. We also publish on this sheet the department overhead figures for that month. A sample sheet as actually sent out for the month of October is shown in Fig. 4. This sheet is distributed to every resident machinist, to each post ord-

nance officer and to the Coast Artillery District Commander. On this sheet attention is called to the fact that the efficiency of any post ordnance officer may be partially judged by the expense he has incurred in the maintenance of his batteries, since such work is done only under his direction under the blanket work order for maintenance of the battery. The efficiency of the resident machinist may be judged by the amount of his local overhead and by the cost of the various modifications he makes, and the efficiency of the department management may be partially judged by the amount of the department overhead.

MATERIAL		
REQ. NO.	INV. NO.	COST

ORDNANCE MACHINE SHOP OPERATION
FOR MONTH OF OCTOBER, 1922.

	Amador	*Sherman*	*Randolph*	*Depot*
Local Overhead Per cent	6	5	8	1.5
Maintenance 1 Mortar Battery	$54.00	$57.00	$57.00	
" 1 14" Battery	45.00	80.00	0.00	
" 1 6" Battery	43.00	27.00	0.00	
TOTALS	142.00	164.00	57.00	
DEPARTMENT OVERHEAD 74 Per cent				
Electrical Equipment 12" M.C. Work Order E-6	41.20	47.60	37.60	
Water Tight Receptacle 12" M.C. Work Order E-47	1.13	1.78	15.95	

NOTE: Explanations, criticisms and comment invited on above statement submitted on attached sheet.

D. WHITTIER,
Armament Officer.

The efficiency of the Post Ordnance Officer may be partially judged by the cost of maintenance of the batteries.
That of the machinist by the amount of overhead and the cost of the various modifications shown.
That of the department by the department overhead.

FIG. 4.

In this way every machinist and ordnance officer has presented to him each month definite proof that his work is being watched and accurate data for comparing his efficiency with that of others doing the same work. He knows that his superiors, the ones to whom he looks for promotion or commendation see his record each month. Every man can see definitely every month his results and have a positive basis for that assurance, which is one of the greatest factors in happiness, that he is earning his pay and putting into a good cause honest effort.

THE NEW RECONNAISSANCE TRACTORS

Continued from page 204

developing 8 to 25 H. P. at 400 to 1800 R. P. M. respectively, with certain modifications required for this vehicle.

The transmission, which is connected to the engine, forming a unit power plant, is of a selective type, having four speeds forward and one reverse. The drive is transmitted through a flexible coupling to the jackshaft. The power is directed from the jackshaft through multiple five-plate steering clutches to pinion drives which mesh with internal gears in the rear wheels.

A propeller, together with a folding steering rudder, is provided for maneuvering in water. A shifting lever is provided for engaging and disengaging the propeller. The drive on the track must be stopped by shifting the transmission clutch to neutral before the propeller is engaged.

The cooling system is of a distinctly modern type. A Sirocco fan attached to the crankshaft draws the air from the driver's compartment, over the engine, through the Sirocco fan, and forces it up through a hood covering the engine and down over the individual cylinders, passing down below the diaphragm forming the floor of the driver's compartment, and back out, exhausting through an opening in the top cover just back of the driver's compartment.

The lubrication of the engine is of the standard type, with the additional feature that the oil is pumped through cooling coils placed in the opening of the Sirocco fan housing, thus securing air-cooling of the oil. This has resulted in a considerable reduction in the temperature of the oil.

The gasoline feed is of a gravity type. The tank has a capacity of twelve gallons and is carried in the fore part of the tractor and above the power plant. The tractor has a gasoline consumption of approximately one gallon for each eight miles over ordinary roads.

The tractor is steered through a bevel gear attached to the end of the steering column, which through a cross-shaft rotates eccentries, which in turn connect to clutches in the jackshaft and control the track drive.

PNEUMATIC EQUILIBRATORS

Continued from page 192.

efficient of expansion of nickel for one degree F., as given by Kent, is .00000695, which, it is seen, very closely approaches the .00000689 coefficient of expansion of tempered steel. If the above tests show results that warrant it, it is intended to replace the silver rings shown in Fig. 6 with rings made of nickel.

Three kinds of grease have been used in the above tests, and the indications are that no improvement in friction can be made through grease. The plunger B is polished longitudinally, and the results of the tests would indicate that there is no grease film between the silver ring and the tops of the minute ridges which are made by such longitudinal polishing. The slight amount of grease which escapes along the plunger, it would seem, flows through the minute valleys between the ridges made by the longitudinal polishing. One of the greases tried was a very high quality graphite grease, but without success.

It is believed that the results of the above tests could be profitably applied to hydro-pneumatic recuperators as well as the equilibrators, as an all-metal assembly such as shown in Fig. 6 would permit the complicated packings and parts of hydro-pneumatic recuperators to be greatly simplified.

Mechanical Testing

By

NICHOLAS RICHARDSON*

IT is obvious that there are close relations between the drafting room and the testing laboratory. Engineers may produce the most brilliant ideas on paper but lacking data on the material proposed for use, designs are very likely to prove at fault.

Modern advance and competition put more and more demand for economy, speed and heavy service together with greatest lightness of construction on all engineering productions, with the result that the danger of "overdesign" is always lurking in the background.

The importance of a study of the methods employed in testing all materials which are used in constructive work cannot well be exaggerated, such study being of vital interest to all having to do with the design, or actual fabrication of any useful article. The subject, however, is too largely neglected even by engineers and others to whom it would seem to be of much more than passing interest, and is very generally ignored entirely by those who do not deal with actual engineering or mechanical propositions. And yet it is full of interest, and is far from being the mass of cut and dried rules and formulas which it is often supposed only to be. Moreover, there is a wide and fertile field where research may be followed, and there are many dark places awaiting rays of light from our general advance in knowledge.

The term "testing," of course, by itself means little or nothing, and requires to be defined by the special quality which it is desirable to appreciate. Materials have many qualities, and tests may be applied to arrive at a measure of one or any quality. The term "testing materials," however, has come into common use to express the testing of materials for the special quality of physical strength, or in a wider sense, their special quality of resisting external forces, and their behavior when subjected to such forces.

In the practice of testing materials two general types of tests are recognized. In the one, a material or sample of a material is submitted to a specified proof test, of which there are many kinds, and should its behavior under the test meet specified requirements, the materials or sample are said to have passed the test. This is a simple and practical type of test which has much use commercially, and gives assurance that the material is strong enough to perform the task for which it is intended, but it does not indicate how much more resistant the material may be, but stops at the point where the material has at least come up to a definite standard.

In another general type of test, an endeavor is made to measure the actual strength of the material under test, and its quality of resistance to various definite stresses is gauged in detail. The first type of test has little scientific interest, but is eminently practical and of very much use in daily commercial practice. The second type of test is of considerable scientific interest and calls for the application of mathematical and mechanical principles, and provides a means of obtaining information of a nature which has been and is very essential to the engineer, designer, metallurgist, chemist, as well as to scientific investigators in many lines.

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Many years ago Newton pointed out that every particle of matter exerted a force on every other particle of matter, and thus every substance of which we are cognizant is perpetually in a state of being acted on by external forces. Material which we see around us is, of course, always resisting gravitational forces, and therefore we shall never have the opportunity of studying anything which is in an absolutely free state.

Mechanical testing as practiced today, and from which a vast amount of useful, indeed essential, information has been and is daily being obtained, is, however, from a truly scientific point of view, at best a somewhat crude performance, but in estimating the subject thus it must be remembered that when we deal with any matters relating to measurements, accuracy can only be obtained in degree and not in an absolute sense.

Our standards of measurement, the pound, the foot, the second, are conventionalities which exist truly only in imagination. The pound is the weight of a certain mass of metal at one spot on the globe, and is as carefully preserved from change as may be. The foot is a definite fraction of the distance between two specified marks located in a definite place and under definite conditions, but to compare these single standards with others even with the highest skill and the utmost refinement of care can only give a result in which there is still an element of uncertainty. It may be, perhaps, that the uncertainty can be shown to be not greater than one-millionth of one per cent—but an uncertainty nevertheless is there. Ideal accuracy must be considered as a matter of degree.

In mechanical testing, fortunately, experience shows that only a very moderate degree of accuracy is necessary, and since mechanical testing is useful primarily because it enables materials to be compared, it does not necessarily entail the employment of expensive and tedious appliances which are essential when a degree of accuracy which can be qualified as "high" is required.

That we can get along so satisfactorily in the engineering world on such a system of approximations as we do is perhaps rather surprising to realize, and the human element of personal judgment as to tolerance, or degrees of accuracy which must be observed is a factor of no small importance.

Mechanical testing in its simplest aspect is the measurement of the changes of shape or condition which a piece under test suffers when acted on by known or (as indicated above) approximately known forces. The reasons why different materials act in different manners under similar conditions are largely unknown. Our knowledge of what has been described as the ultimate structure of material of any kind is very limited. Although much advance has lately been made in the search for a conception of the ultimate particle, very little so far has been discovered which explains why certain substances have certain characteristics. What, in fact, enables a material to exhibit such physical qualities as elasticity, hardness, strength—we do not know.

The commonest and possibly the most useful of all tests in the general run of testing is the tension test, in which

the behavior of a material is noted when it is subjected to a simple pull or, as it is called, is subjected to tensional stress.

Although material of any type can of course be submitted to mechanical testing, the following remarks will be confined chiefly to metals.

Tensile testing machines, after long years of use, have been brought to a considerable degree of excellence, for although it would appear to be a simple mechanical feat to design and build a machine which will give a straight and variable pull, and at the same time indicate the amount of the pull with sufficient accuracy, a close examination of all the requirements necessary to be filled will make it clear that the problem is not easy. At the present day, however, there are many types of such machines on the market which are capable of giving results quite sufficiently accurate for engineering purposes. The results of a tensile test, for example, on a specimen of steel intended for use in some mechanical structure are in the vast majority of cases reported in a way which must be somewhat confusing to an unexperienced observer who may be interested. An engineer in designing some special machine wishes, of course, to know the strength of the steel which he intends to use. He therefore asks for the elastic limit, the ultimate strength, and the percentage of elongation and contraction of area of a specimen of that steel as determined by an ordinary tensile test. The test is made and results are reported as above. As a matter of fact, the true results are not what they are reported to be, and it is possible that there are many engineers who do not truly appreciate that the results of a tensile test are reported conventionally in a sort of technical jargon, of crude and inaccurate statements.

The terms elastic limit, proportional limit and yield point have entirely different meanings, and although it is true that in a material like steel these points may be very close together, it is unfortunate that there is so general a looseness in their use. The elastic limit and the proportional limit are extremely difficult to ascertain with more than a very moderate degree of accuracy, even with the best of instruments in the hands of careful scientific observers. In the case of the yield point, there has been much discussion as to what really constitutes the phenomenon commonly known as the yield point.

The result which is reported to the designing engineer as "the elastic limit" or "the yield point" should be recognized as a simple numerical approximation of a phenomenon exhibited by a material under stress when it is passing from the elastic to the plastic phase.

Again, it is not always understood that the reported ultimate, or tensile strength, is only a conventional figure. This result is practically always reported in pounds per square inch of the original cross section of the tested specimen, whereas the specimen has become reduced in cross sectional area before the ultimate load is reached, and often does not break until this cross sectional area is very much reduced.

It will be thus seen that the engineer obtains a series of approximations on which he bases his calculations, and after all has been done, a factor of safety is introduced, such factor being the reserve which, it is hoped, will cover the unknown.

It is not to be inferred from the foregoing that the value of ordinary tensile testing is any the less, and that mechanical testing is simply a series of guesses. The explanation of this apparent carelessness lies, not in the failure to obtain test results which are of a very considerable degree of accuracy, but in the character of most of the materials which are available for structural purposes. Commercial material which is homogenous, and constantly of similar nature throughout, does not exist.

Two test specimens of exactly similar dimensions, and made from material actually contiguous in an original mass of steel will not give exactly similar results when tested under the same conditions. The results may be very nearly alike, but they will not be the same. This is not surprising when the physical composition and structure of the steel is considered. Microscopic examination of steel shows it to consist of an agglomeration of crystals of different materials, of different sizes, and differently orientated, and joined together by a matrix of non-crystalline material possibly different again in composition to the crystalline matter. The stresses to which the test piece is subjected are borne by these crystals and the amorphous matrix. What we therefore measure is the combined resistance to stress of a host of different minute individuals and the cementing matter which causes them to adhere together, and since the component particles differ, their individual resistances are different. The combined resistance of the particles in a unit cross section area is very similar though not identical with the combined resistance of the particles in any other unit cross section area of the same material.

It is also to be observed that it is impossible to make two heats of steel exactly alike in composition, a consideration which is very evident when a very cursory survey is made of the processes necessary in making steel, from the blast furnace to the steel conversion furnace, and if the changes which that steel may undergo in the various types of heat treatments adopted are also taken into account, it will be clear that two pieces of steel derived from different heats will be similar in general character rather than identical in every respect, however, great care is taken to duplicate operations in every way possible.

Investigations have been made of the resistance to various stresses exhibited by single crystals of the substances which make up the material known as steel. In this case of course the tested material is in a state of homogeneity as perfect as is known, but an exact knowledge of this resistance does not assist much, since the sizes and dispositions of each crystal in the mass differ.

The futility of super-refinements in recording the observations made in routine tensile tests is therefore evident, but it also shows that it is unsafe to take the recorded results of a test on one sample of a steel as a measure of that steel. It is more satisfactory to form a judgment from the result of three or more samples, taking the average of three or more if the figures are near, but discarding any one which diverges greatly from the others.

These conditions, of course, apply in exactly the same way in other tests which are commonly made in routine laboratories, such as bending, torsion, and shear tests, and it is recognized that the results reported from the laboratory are indications more of the order of magnitude of physical resistance of the tested material than absolute determinations of actual strength.

There are certain tests the results of which can only be used in a comparative sense, in that such tests only determine the difference of resistance to certain types of stresses between one material and others. This is well exemplified by the impact test and certain types of endurance or fatigue tests. Such tests are somewhat complicated by the introduction of factors which are up to the present largely unknown, and the reliability of such tests depends to a certain extent on the reasonable supposition that these unknown factors can be maintained as constants from test to test.

Much assistance has been given and much has been done to advance the usefulness of general testing, perhaps better

expressed as the usefulness of laboratory test results, by the standardization of tests and testing methods. It is evident that a satisfactory series of standards will clarify and simplify much data which emanate from various testing establishments. The difficulty, of course, lies in the proper standards to adopt, and there is also an added danger that a standard, once adopted to any great extent, will act as a hindrance and discouragement to research and refinement.

The work which is carried on in such a testing laboratory as that at Watertown Arsenal might be considered as falling into two distinct classes. In the first class are included proof tests and routine tests, and in the second class all tests of a purely investigative nature. In the first class speed and reliability are the objects aimed at in order that other departments, asking for the tests, may be supplied with the information they require without delay. By reliability, it is meant to convey the assurance that such routine tests give results which certainly do not diverge from the truth by more than by a certain percentage which in the case of Watertown Arsenal laboratory is very small. It is in testing of this kind where the adoption of national, or at any rate widely recognized, standards is of the greatest assistance, which adoption facilitates the ready making of comparisons with routine work done at other laboratories, and simplifies much of the work.

In the case of investigative work, however, a very high degree of accuracy may be arrived at, and approximations of absolute measurements obtained. Standardization in research work can only be useful in a restricted sense.

The opportunities in the past for research and experimentation for the improvement in testing methods and, indeed, in all matters pertaining to the exact examination of the physical properties of materials of construction have not been as great as might have been wished. The expense involved in the support of a laboratory, the cost of proper testing machines, the employment of personnel of the right calibre of mind, and the cost of obtaining proper test specimens in sufficient number—this last item being one of the utmost importance, and one which is too often forgotten—has prevented research from being carried on to any great extent, except at endowed universities or State aided or supported institutions. The general run of producers, even now, cannot see sufficient return in dollars for an adequate investment in research, and only a comparatively few commercial concerns look upon the maintenance of an efficient testing laboratory as anything but a burden, or at best as a necessary evil, assisting only in the production of materials of a minimum rather than a maximum quality.

Again, much duplication of work in experimentation unfortunately takes place on account of the lack of a satisfactory clearing house of information. Very frequently elaborate and expensive investigations are planned and carried to completion, and only then is it discovered that the work has all been done before, the results having been published in some obscure quarter, or possibly not published at all. Too much stress cannot be laid on the value of thorough search of literature before any actual experimental work is undertaken. It is true that the repetition of experiments has occasionally resulted in the securing of some new fact, passed over by a previous observer, but in the great majority of cases nothing is discovered which has not already been recorded, and which is to be found by a diligent examination among the proper literatures. Possibly it is an exaggeration to say that half the investigative work carried out in the laboratories of the country is useless repetition, but unquestionably the proportion of duplicated work is very great.

Radiography of Metals

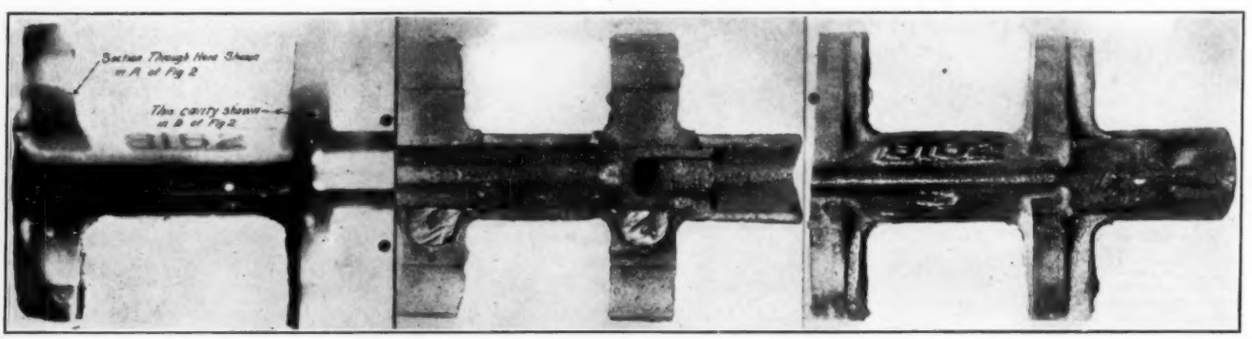
Watertown Arsenal

By

H. H. LESTER

THE technique of radiographic testing of metals is sufficiently novel that in view of present interest in the subject a description of the method should be of interest to readers of ARMY ORDNANCE.

From the first discovery of X-rays by Roentgen in 1895, there has been a lively interest in the question of X-ray penetration in opaque materials. A great deal of work on penetration has been done by physicists, mostly in Europe,



A B C

Fig. 1. Pictures of a Ground Casting

1-A Radiograph. 1-B Ordinary Photograph taken from same position as 1-A. 1-C Ordinary Photograph from reversed position.

and the laws of penetration fairly well established. The X-ray method for examining hidden details of structure was presented at the beginning to the medical profession and the development of radiography technique has been largely in the hands of the medical profession or concerns who have specialized in medical apparatus. During the war, however, attention was given to this method as a possible device for testing materials. Considerable use was made of it in England for testing aeroplane materials, and with marked success in locating structural defects. In this country the method was used at the General Electric laboratory for testing turbine blades. The method has been used to some extent in Germany during and since the war for testing metal castings, concrete reinforcements, etc. So far as known, the X-Ray Laboratory at Watertown Arsenal is the only one that has been fitted up especially as a part of a metals testing laboratory and where the results of the X-ray tests are applied directly to control foundry practice.

The radiographic process is essentially a photographic process. The metal to be radiographed is disposed between the target of a Coolidge X-ray bulb and the photographic film. After exposure the negative is developed in the ordinary way. Fig. 1 gives an idea of the kind of negative that results. In this figure A is a radiographic picture of a steel grouser for a tank track shoe; B is an ordinary photograph of the same casting taken from the same point of view; and C is a similar photograph taken from the opposite side. A comparison of these pictures shows that the ordinary photograph is superior to the radiograph in the

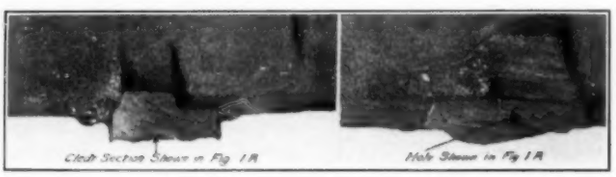


Fig. 2. Photographs of Sections Indicated in Fig. 1-A.

greater amount of surface detail, but the radiograph does show surface detail and shows, in one picture, details of both surfaces which can be secured with a camera only by taking two pictures; in addition the radiograph shows details of internal structure. White spots represent thin metal. This may be due to the presence of cavities or may be due to the geometry of the casting. Cavities are usually represented by small irregular areas and can be distinguished readily from the regular design of a structural detail.

Enlarged sections of the casting shown in Fig. 1 are shown in B and C of Fig. 2. Fig. 3 is a radiographic picture of a particularly bad grouser casting. This casting was similar to the one shown in Fig. 1 and did not show external evidence of its internal condition except for a pin hole in a thin portion of the metal and cavities immediately under the risers. Note the stream lines that indicate the path of the gas bubbles as they coalesced to form the larger cavities in the thicker part of the metal.

The pictures here shown were all taken through relatively thin metal. It is important to know through what thickness of metal pictures may be taken. The absorption law tells us that for homogeneous X-rays—that is, X-rays that are essentially monochromatic—each increment of thickness absorbs an equal fraction of the radiation upon the sheet of metal represented by that increment. Also we know that the penetration varies directly with the potential applied to the tube. These facts give us a law that would express the penetration in terms of potential and exposure if we were exposing an ordinary film in an ordinary way to the transmitted radiation. However we do not do this, the film to be exposed is mounted between two sheets of fluorescent material known as intensifying screens. These screens glow under the influence of X-rays and the photographic action recorded is the sum of that due to the direct

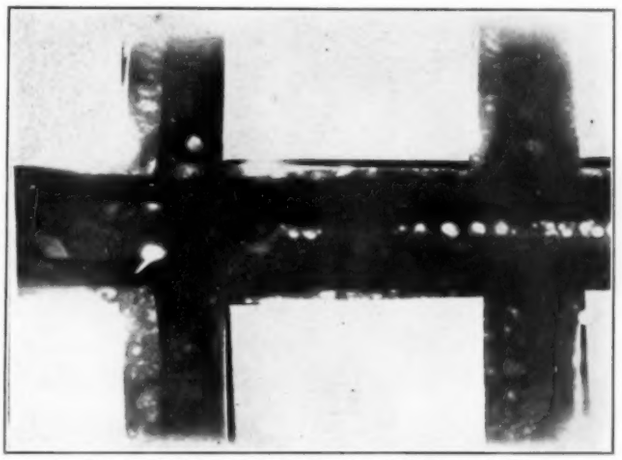


Fig. 3. Radiograph of a Particularly Bad Gouser Casting

action of the X-rays on the film plus that of the screen glow or fluorescence. The latter effect may be ten times the former. The fluorescence varies with the wave length of the exciting radiation hence the known absorption laws do not give us the necessary data to predict with certainty the penetrating power of a bulb when used with intensifying screens which are used in metal work. Recent experiments in this laboratory have given an empirical law for steel with the film 17 inches from the target, however, which within the limits of our machine gives satisfactory results. This law is expressed by the equation:

$$y=(.0048V-.26)\ \log\ x$$

where y is the thickness of metal expressed in inches; V is the potential across the bulb expressed in kilovolts; x is the product of the thermionic current through the bulb by the exposure time in seconds. We have called this product the "exposure." This equation has been tested with satisfactory results down to 80 k. v. It does not hold for small values of V, but probably does hold for values of V above

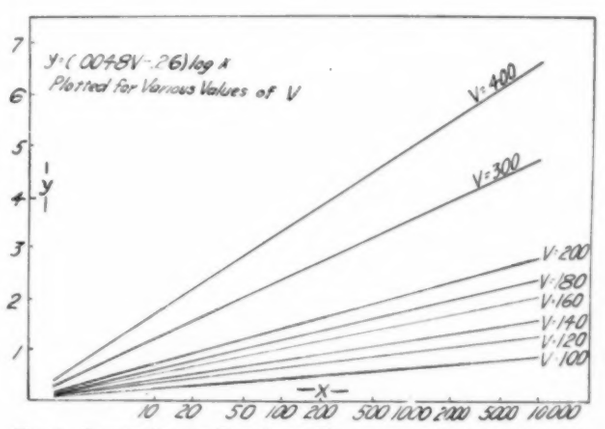


Fig. 4. Penetration as a Function of "Exposure" at Constant Voltages

200 k. v., which is the upper limit of our machine. This equation is plotted for various values of V in Fig. 4.

We have taken thirty minutes as the upper limit of practical exposure time. Longer exposures would increase the expense of the test without greatly increasing the amount

of material that could be penetrated at a given potential. In cases of sufficient importance longer time could be given but there would be very little return in penetrability for the extra energy expended. Reference to Curve A in Fig. 5 illustrates this point.

After the bend in the exposure curve is reached the pene-

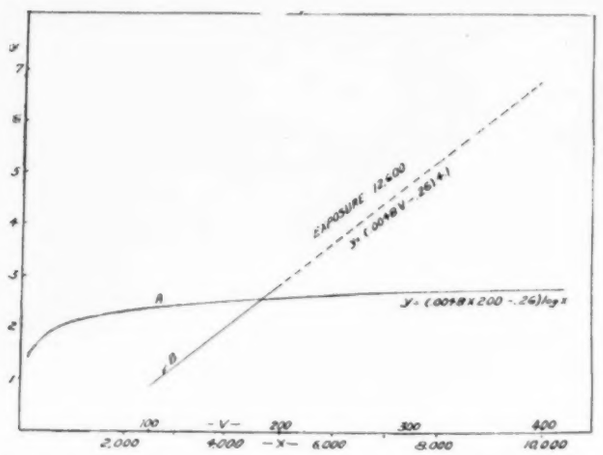


Fig. 5. Curve A. Penetration as a Function of "Exposure" with 200 kilovolts across the belt
Curve B. Penetration as a Function of voltage with a Constant "Exposure" of 12,600

tration increases very slowly with the exposure. The maximum potential we can use at present is 200 k. v. and the maximum safe bulb current 7 m. a. This, with an exposure time of 30 minutes, gives an "exposure" of 12600. If we fix the exposure then at 12600 the curve B of Fig. 5 gives the penerration to be expected between 70 k. v. and 200 k. v. It is evident that we can penetrate just under three inches of steel with a photographic film 17 inches from the target of the bulb. We have in practice penetrated 3.1 inches in thirty minutes, but the film was 13 inches from the target.

If we may extrapolate Curve A of Fig. 5 for values of V greater than 200 k. v., it is seen that a 300 k. v. bulb should penetrate 6.8 inches of steel. Such bulbs are needed and will undoubtedly be developed. Bulbs of greater current capacity will also be developed. But increasing the current capacity will have far less influence on the penetration than increasing the potential.

It is often of importance to know the exact dimensions of a fault. We can under certain conditions get a definitely outlined image that will show a fairly accurate outline of cross section of the fault. This is shown in Fig. 3, where the stream lines formed by the gas in the metal are shown in definite outline. In this particular case the film was close to the metal of that part of the casting and the cavities were relatively large. For cases where the cavities are some distance away and are relatively small as compared to the area of the focal spot on the X-ray target the cavity acts like the aperature in a pin hole camera, and the image becomes a blurred image of the focal spot of the target rather than an image of the flaw. In general, the cavity must be large enough that the pinhole effect is not important. This again depends upon the distance of the film from the cavity and from the focal spot. It has been contended that there would always be a tendency for blurred images due to the effect of scattered radiation from part of the metal next to the film. Our experience has not shown this to be true. A very definite image was obtained from a V-shaped opening in a lead plate that was 4 inches from the film and radiographed through 3 inches of solid steel disposed between the lead and the film. This image was faint and not reproduceable for illustration, but the edges were sharp. In the cases that come up in practice the cavities are often roughly spherical. In such cases where the cavity occurs in thick metal the image appears dense in the center and shades off to the edges. The edge may in fact be too faint to be distinguishable. In such cases a definite outline cannot be obtained even though the pinhole effect does not enter.

To get the area of the cross section of the fault it must be remembered that the X-rays proceed from a small area that approximates a point and radiate from this point in all directions. In passing through a spherical cavity a conical pencil of rays would be intercepted by the cross section of the cavity. The intersection of this cone with the film would define the image. The areas of the section of the cavity and the image would be related as the squares of the altitudes of the two cones, as in geometry, for the case where the film is perpendicular to the axis of the X-ray beam. If the cavity is not spherical and is inclined to the axis of the beam then the area of the image will be a scenographic projection of the sectional area of the fault subtended by the rays proceeding from the target. In general, we do not know how the cavities lie with reference to the film so that it is usually not possible to measure the sectional area of the fault even when we have definite images, which is not often. In cases of sufficient importance the lay of the flaw may be determined by a steroscopic examination and fairly accurate dimensions determined where definite images are obtainable.

In Fig. 7 the loss of definition due to the pinhole effect is illustrated. These pictures are radiographs and some of them closely resemble effects found in actual practice. A is a radiograph of a piece of lead sheet ⅛-inch in thickness that contained some drill holes, the smallest of which was .032 inch, the largest .227 inch in diameter, and a large irregular hole made with a file. The film was 1 inch from the lead sheet. Note that the image is clear cut, even shreds of metal left by the drill or file showing. Care was taken

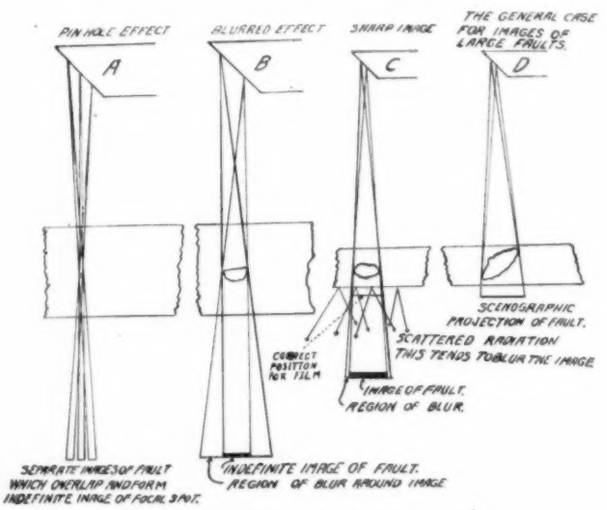
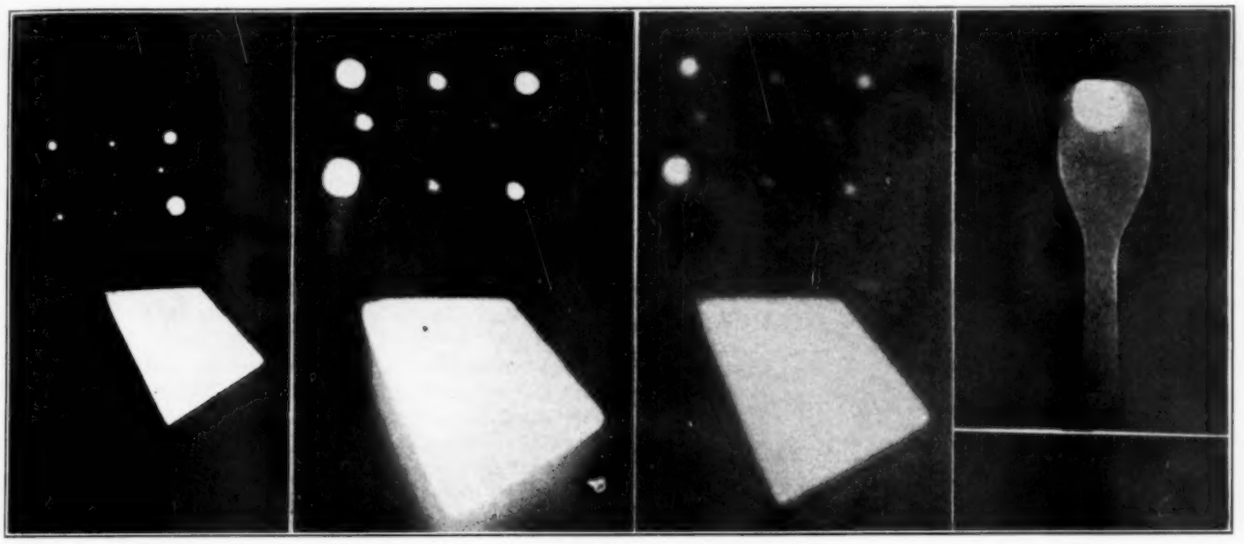


Fig. 6. Effect of Various Relations on Definition

to clear the smallest hole. Metal shreds were left in some of the small holes so as to give in effect irregular small holes. B shows the same set of holes, in this case with the metal moved to a position 11½ inches from the film. In this case there is a distinct loss of definition in all of the images. The smaller holes now give pinhole images of the focal



A B C D

Fig. 7. Radiographs Through Lead Plates

7-A. Lead Plate 1 Inch from Film. 7-B. Lead Plate 11½ Inches from Film. 7-C. Lead Plate 11¾ Inches from Film with 0.35 Inches of Steel Interposed 7-D. Pinhole Radiograph of Focal Spot, Target and Stem

spot of the target. This image is the same for the cleaned central hole as it is for the other small holes that contained metal and were in effect irregularly shaped holes. The larger images show the general contour of the holes they represent with a region of blur at the edges. This indefinite region becomes less marked as the size of the hole is increased, but does not disappear even in the largest area. These effects are shown diagrammatically in Fig. 6. The radiographs shown in B were taken without the interposition of metal between the lead and the film other than the aluminum top of the cassette holder. In C there was interposed .35 inch of steel, placed just under and in contact with the lead. For this case the film was 11¾ inches from the lead. Inspection of C shows that there is some gain in definition over that found in B. This is particularly noticeable at the corners of the large image. We have observed in this and in other cases that the definition of the image is not destroyed by the effect of characteristic radiation from the underside of the metal. We emphasize this point because the effect of the characteristic radiation is often referred to in the literature on radiography.[1] W. P. Davey [2] made a similar observation several years ago. There is an effect due to the characterisic radiation that is evident in C. This is a general fog which tends to destroy the contrast between the image and the adjacent film, but this does not seem to destroy the definition.

There are some other interesting features in the pictures shown in B. The long "tails" under the round images and the corresponding trail of "light" from the large opening are due to the characteristic radiation from the tungsten target. The main penetrating radiation proceeds from the focal spot on the target, but in addition to this radiation there is a characteristic radiation from the total surface of the target and even from the stem supporting the target. This radiation is completely absorbed by the metal in ordinary radiography. In this case no metal being present, it appears in the negative. The "tails" may be caused to point in various directions by rotating the tube with reference to the lead plate, the "ghost" of the large image that appears beneath the more definite image is due to the radiation from the face of the target, the more extended tail is due to radiation from other parts of the surface of the target and stem. A better illustration of the effect of the characteristic radiation from the target and stem is shown in D where we succeeded in getting a pinhole radiograph of the focal spot, target and a part of the stem supporting target.

The focal spot of the tube is shown in the images of holes smaller than .06 inch in diameter. It is shown better in Fig. 8. These pictures were taken through a pinhole .017 inch in diameter in 1/16 inch lead sheet and at a distance of 18 inches from the film. The target was 36 inches from the film. As mentioned above, an image of the whole target was obtained which shows the relation of the focal area on the target to the total area of the face. This area can be seen by visual inspection of the target because it is roughened under the cathodic bombardment. Fig. 8 shows some images of the focal spot. It is evident from these pictures that the focal area consists of a series of spots mostly grouped around the center and that from each of these spots there is a spiral trail leading into a circular exterior band with the group of dense spots at the center. Evidently the cathode stream plays back and forth between the outer circle and the inner spots and moves by definite paths from the spot to the circle. These paths are always spiral, but the spots vary. A single arrangement of spots persists for a considerable length of time. After the tube has been resting for a few hours new spots are apt to appear upon starting it up again. In Fig. 8 some of the spirals were slightly retouched to bring them out more strongly for reproduction.

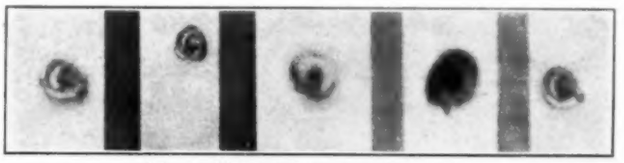


Fig. 8. "Pinhole" Images of Focal Spot

In the images of the larger holes in Fig. 7, B and C, there is a dense line just inside the image and following

[1] cf. Janus & Reppchen—also Respondek—Trans. of Roentgen Soc., Vol. XV, Part 2, 1919.

[2] Dr. W. P. Davey, G. E. Review 18, P. 241—1915

the contour of the image except that in the case of the large irregular image the line does not reproduce the contour at the corners. These are rounded, in fact this line seems to give the rounded corner effect in B. The line is evident in C, but is relatively less dense, so that the corners appeared much more definite when the iron was interposed. This more definite appearance of the corners might have

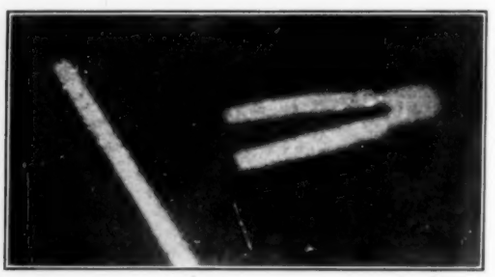


Fig. 9. Radiograph of Pieces of Lead Taken Through 2.35 Inches of Lead

been due, however, to the fact that much shorter wave lengths were used when radiographing through the iron, also the iron filtered out the characteristic radiation from the tungsten so that this fact further shortened the wave lengths that were active in forming the image. As to the cause of this line, it is undoubtedly due to diffraction from the lead crystals in the vertical surface of the holes, and represents the strongest of a number of lines that could possibly be found with suitable apparatus. Such a line would show rounded contours at the corners. The effect of this line on the definition is to cause rounded corners in such a cavity as we have radiographed in the above series. It also, however, gives a pronounced edge to the image which is quite noticeable in the print, although it may not be so definite in the reproduction. For a small distance between film and object the effect is noticeable. As this distance is increased the line travels towards the interior of the image. That the radiation in this line is more penetrating than that characteristic of tungsten is shown by the fact that the "tails" in B could be about 90 per cent absorbed by .045 inch of transformer iron and could not be detected through ⅛ inch of steel, while the diffraction or reflection line is still strong through .35 inch of steel. That this radiation is less penetrating than the radiation from the focal spot is shown by the fact that the line is relatively less pronounced in C which was taken through .35 inch of steel.

To determine the dimensions of the cavity in a direction parallel to the axis of the X-ray beam it is necessary to consider the relative density of the image to the density of the film adjacent to the image. Unfortunately the density of the film is not a linear function of the exposure so that except in cases where there is very little difference in density the comparison of densities does not give an accurate estimate of the diameter of the cavity. We make rough estimates of this dimension based on experience gained in comparing negatives with castings that have been cut up to show the flaws. These estimates are rough and often entirely wrong. It is expected to attack the problem in this laboratory in the near future and work out some relations between relative density and diameter of flaw that will serve as a guide to improve our technique in this respect.

Fig. 9 shows the radiograph of two pieces of lead taken through 2.35 inches of steel with the film 4 inches from the lead. The pieces of lead were cut from 1/16 inch lead sheet and one piece was bent around the end of a screwdriver and squeezed tight with pliers. In these the characteristic radiation from the lead is entirely absorbed and the definition is consequently sharper. There is no rounded corner effect even in the sharp internal angle shown by one of the pieces.

Of greater importance perhaps than the exact dimensions of flaws is the question of detectability of flaws. Experiments carried out in this laboratory indicate that where the linear dimension of the flaw, that is the dimension parallel to the axis of the X-ray beam, is approximately equal to 1½ per cent of the total thickness of metal in the region adjacent to the flaw the image may be distinguished. We have placed the detectability at 2 per cent for practical working conditions. When working with thin metal or with fairly large images in thick metal we have detected the image for differences in thickness of metal no greater than 1 per cent, but this case is not the usual case and as one of our workers said, "involves some strain on the imagination." With a 2 per cent limit we could detect a cavity .05 inch in diameter in metal 2.5 inches thick. The surface markings on a casting very often are of greater magnitude than the internal cavities. In order to distinguish between the external marks and the internal faults the negative may be compared to the original casting. In cases of doubt recourse must be had to stereoscopic examination which settles the matter definitely. To locate a cavity within the metal the stereoscope again comes into use. In making a stereoscopic examination the area to be radiographed is arranged so that the center of the area, the center of the film and the target are in line, then the bulb is moved three centimeters to one side of the center line and the exposure made. A second negative is made with the bulb three centimeters to the other side of the center line. These two negatives after development are placed in a stereoscope so arranged that the films may be as far from the eye as they

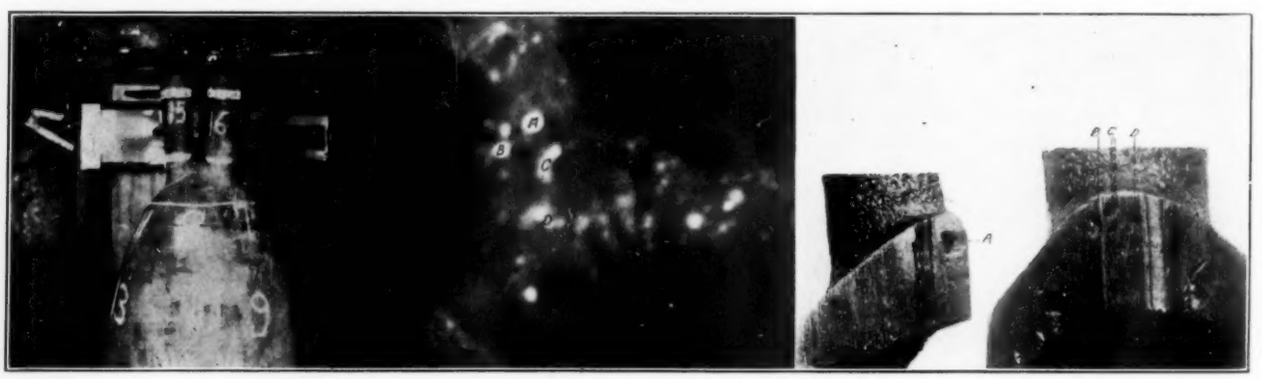


Fig. 10-A Fig. 10-B Fig. 10-C

Fig. 10. Example of Routine Test

10-A. Ordinary Photograph of Nose of Bomb. 10-B. Radiograph of Same. 10-C. Sections Showing Defects Revealed by Radiograph

were from the target of the bulb when the exposure was made. When the machine is properly adjusted the picture stands out in bold relief. The surface markings and structural details serve to outline the picture and the faults appear in their proper places within the material. The picture is quite striking and gives the illusion of looking at a transparent model of the casting. By reversing the negative this model may be turned completely over so that one may look through the casting from the other side. The method permits locating details with reference to other details of interior structure. As yet we have not attempted to measure depth of fault in linear units.

Figure 10 is an example of the routine tests as carried out here. The casting for the nose of a drop bomb, shown in A, was sent in for radiography before the risers were cut off. The casting weighed about 400 pounds and stood about 40 inches from the floor. The areas to be radiographed were marked off, numbered, and prints of the radiographs properly indicated were furnished to the foundry. Only one area showed serious cavities. This one taken through the nose parallel to the axis is shown in B. It was evident from the location and magnitude of the faults that the risers were not feeding properly; a change in the design of these remedied the difficulty. This particular casting was discarded and we were permitted to cut it up for study. Due to the shape of the nose it was not possible to get the film within about 10 inches of the metal that was radiographed. For this reason we expected the details in the negative to show indefinite outlines. We also expected the surface markings to show because the casting was rough. Inspection of the negative verified our expectation. There were some "spots" however that showed definite outlines and some that were less blurred than others; some were blurred in parts and more definite in other parts. The clear outlines indicated large cavities, those with blurred edges should indicate smaller cavities, those with edges fairly definite in some places and very indefinite in others should indicate fairly large and irregular cavities inclined to the axis of the X-ray beam. The very indefinite spots, light in the center and shading off towards the edges, represent very small cavities; in these the pinhole effect predominates and the shape of the image bears no relation to the shape of the fault. The section through the nose shown in C illustrates the above points. The fault indicated at *a* in C illustrates also a point made above in discussing the areas of faults, and illustrated in D of Fig. 6, that is the area of the image is a scenographic projection of the fault from a point of view in the surface of the target. The area of the fault cannot be determined ordinarily from the area of the image.

(ARMY ORDNANCE is very fortunate in being able to present to its readers the above very interesting article on the Radiography of Metals, by Dr. H. H. Lester, Physicist at the Metallurgical Laboratory, Watertown Arsenal. This is pioneer work and its future development will doubtless be of great importance to the industrial world.—ED.)

The Muscle Shoals Nitrate Plant

Its Relation to the Nitrogen Supply

By

JOHN K. CLEMENT
Member A. O. A.

THE World War called attention of the public to the importance of nitrates in warfare. More recently interest in the requirements of nitrogen for agriculture and industry has been aroused by the offer of Henry Ford to purchase and operate the Government's large nitrate plant at Muscle Shoals.

Nitrates are indispensable in warfare, because of their use in the manufacture of all explosives. They are equally indispensable in agriculture and industry because of the fact that they are essential to our animal and vegetable life, as well as to many more important industries.

Nitrogen is essential for the manufacture of practically all explosives. The nitrogen of black powder is furnished by saltpeter or potassium nitrate.

Prior to the latter part of the Nineteenth Century the nitrogen of explosives was always introduced in this form. In 1887 Vielle, a French chemist, showed that cotton when treated with nitric acid and sulphuric acid forms nitrocellulose or guncotton, which is the basis of smokeless powder. It has been found that a number of bases may be treated with nitric acid to form explosives. For example, glycerin yields nitroglycerin; toluol, trinitrotoluol or T. N. T.; phenol or carbolic acid, picric acid; and ammonia, ammonium nitrate.

The tremendous expenditure of ammunition in modern warfare has greatly increased the importance of the supply of fixed nitrogen. In this connection it is of interest to compare the expenditure of ammunition in the World War with that of our own Civil War.

In the battle of Gettysburg, the Union Army consumed 32,781 rounds of ammunition; while in the battle of the Somme, in 1916, the British expended 4,000,000 rounds. During the entire Civil War the Union Army expended 5,000,000 rounds of artillery ammunition. During the World War the British and French expended 12,710,000 rounds in *one month*.

The consumption of nitrates during the war reached enormous proportions. In the United States, for example, it has been estimated that the consumption of nitrogen in the manufacture of military explosives during the year 1918 amounted to 151,000 tons of nitrogen, equivalent to approximately 1,000,000 tons of Chile saltpeter. The Hindenburg program of August, 1916, called for an annual nitrogen consumption of 265,000 tons.

Aside from military requirements the largest demand for nitrogen is for the production of fertilizers. Nitrogen together with potash and phosphorus is essential for the growth of plants. These elements are removed from the soil by growing crops and in order to maintain the fertility of the soil the farmer returns them in the form of fertilizer. Formerly the sole source of fertilizer material was the animal and vegetable refuse of the farm. The quantity of this kind of fertilizer has for a long time been inadequate and for fifty years or more an increasingly large proportion of the plant foods has been supplied by so-called commercial fertilizers.

The nitrogen of commercial fertilizers is supplied by two classes of materials—organic and inorganic. The important organic materials are cottonseed meal, animal tankage and dried blood, and fish scrap. The most important inorganic materials are nitrate of soda and sulphate of ammonia.

Each of the two classes now furnishes about one half of the total nitrogen. During the past twenty years there has been a marked increase in the proportion of inorganic nitrogen in mixed fertilizers and a corresponding decrease in the quantity of organic nitrogen. This change is due both to the fact that the organic materials are by-products of other industries and, therefore, the supply does not respond to the demand as well as to the growing use of the organic materials for cattlefeed. The result is an increase in the use of inorganic nitrogen in fertilizers at a rate that is even more rapid than that of the consumption of fertilizer itself.

Approximately one-half of the inorganic nitrogen consumed in the United States is used in the production of fertilizers. The balance is about equally divided between industrial explosives—used in the mining and quarrying industries, for road building, clearing land, digging ditches and for other purposes—and in the chemical and other industries—e. g., refrigeration, the manufacture of artificial leather, celluloid, dyes, drugs and heavy chemicals and for glass making.

The consumption of inorganic nitrogen has been increasing at the rate of ten per cent per year. It now amounts to about 200,000 tons of fixed nitrogen, which is equivalent to 1,000,000 tons of ammonium sulphate or 1,000,000 tons of sodium nitrate.

Supply of Nitrogen.—There are three important sources of inorganic nitrogen, each of which now supplies approximately one-third of the world's requirements. They are:

1. The nitrate beds of India and Chile.
2. By-product coke ovens and gas plants.
3. The atmosphere.

For several hundred years the world's supply of saltpeter came from the nitrate beds of India. This supply is, however, limited and since 1830 the nitrate beds of Chile have been the chief source of supply.

Bituminous Coal.—The second source of supply is the by-product coke oven and the coal gas plant. Bituminous coal contains from 1.0 to 1.5, and in rare instances as much as 1.8 or 2.0 per cent nitrogen. A part of this nitrogen is recovered in the form of ammonia when coal is heated in gas retorts or in by-product coke ovens. The by-product coke industry of the United States which, prior to the World War, lagged behind that of both Germany and Great Britain is now second only to that of Germany.

The third source of inorganic nitrogen, the nitrogen of the air, has been developed within the past two decades. Since 1914 the nitrogen fixation industry has grown by leaps and bounds. In 1920 the production of nitrogen from the air exceeded that from either of the other sources. The figures are as follows:

Chilean Nitrate	422,685 tons
By-product ammonia	391,400 tons
Fixed atmospheric nitrogen	469,130 tons
Total	1,283,215 tons

Of this quantity the United States consumed 325,926 tons and produced 104,845 tons.

Development of Nitrogen Fixation.—The earth's atmosphere contains an inexhaustible supply of nitrogen, approximately four-fifths of the air being nitrogen. The nitrogen of the air is unfortunately extremely inert and until very recent years eluded the efforts of the chemist to fix it in a form to which it might be available to mankind.

There are now three processes for the fixation of nitrogen in successful commercial operation. They are:

The arc process.
The cyanamid process.
The synthetic ammonia (Haber) process.

Arc Process.—This process utilizes the fact that when air is heated to an extremely high temperature the nitrogen and oxygen combine to form nitric axide. On cooling the nitric axide combines with more oxygen to form nitrogen-peroxide, which may then be absorbed in water to form nitric acid. The arc process was the first fixation process to be placed in successful commercial operation. It was developed in Norway and the first plant was built in 1903. This process requires an enormous amount of electric energy—8.41 K. W. years per metric ton of nitrogen—and for this reason can only be used where power is abundant and cheap. It has been developed chiefly in Norway.

The Cyanamid Process.—The cyanamid process is based on the fact that at a temperature of about 1,000 degrees C. calcium carbide combines with nitrogen gas to form calcium cyanamide. Calcium carbide has been manufactured in large quantities for a number of years for use in the production of acetylene gas. It is a product of the electric furnace and the raw materials are lime and coke. The reaction is, $CaO+3C=CaC_2+CO$. The calcium carbide which is removed from the furnace in a molten state is first cooled and ground and then heated in electric ovens in an atmosphere of nitrogen. At the proper temperature the carbide and nitrogen react as follows: $CaC_2+N_2=CaCN_2+C$.

This is the process in which nitrogen is fixed. The first commercial plant built was in Italy, in 1906. Since then plants have been erected in Germany, Norway, Sweden, Austria and Hungary, France, Japan, Switzerland and the United States. For this reaction a pure quality of nitrogen is required. Nitrogen gas may be separated from the air by several different processes. At the Muscle Shoals plant the Claude liquid air process is used. The separation of the nitrogen from the oxygen is effected by a fractional liquefaction and distillation of air at low temperature.

The power requirement is large—about 2.0 K. W. years per metric ton of nitrogen fixed. In order to compete with other sources of fixed nitrogen a supply of cheap power is essential.

Cyanamid can be used directly as a fertilizer, in limited quantities. It is readily converted into other useful chemical compounds. For example, by dissolving it in water and heating it under a pressure of from 50 to 250 pounds

steam, its nitrogen may be converted into ammonia; $CaCN_2+3H_2O=2NH_3+CaCO_3$.

Synthetic Ammonia (Haber) Process.—The last of the three important fixation processes to be developed was the synthetic ammonia or Haber process which was established in Germany in 1913. Prior to the end of the war it had not been successfully operated in any other country. In this process ammonia is formed directly by the combination of nitrogen and hydrogen in accordance with the reaction $N_2+3H_2=2NH_3$. Simple as this equation looks, the reaction is very difficult to bring about. It requires a suitable catalyzer and in order to obtain satisfactory yields the gas must be under high pressure—not less than 100 atmospheres. The temperature is about 500 degrees C.

One of the requirements, as well as one of the principal difficulties of the process, is a supply of pure nitrogen and hydrogen gas. The nitrogen, of course, is taken from the air. The hydrogen is produced from water usually by passing steam over coke in a water gas generator. Where power is plentiful and cheap it may be obtained by the electrolysis of water. The great advantage of the process is its low power requirement—0.42 K. W. years per metric ton of nitrogen fixed.

Other Process.—A considerable amount of experimental work has been done on a number of other processes for nitrogen fixation, including the elumonum nitride process and the Bucher Cyanide process in which sodium cyanide is produced from the reaction of nitrogen, carbon and sodium carbonate in the presence of an iron catalyzer. A small experimental plant using the latter process was erected during the war at Saltville, Va.

Developments During the War

At the beginning of the war Germany had on hand a large amount of sodium nitrate. With the capture of Antwerp she obtained important additional quantities which, with her original stocks, gave her a sufficient supply for a war of perhaps one year's duration. When her commerce was driven from the seas her supply of Chilean nitrate was, of course, shut off. When it appeared that the war would not be over in a year, Germany realized the necessity of greatly increasing the capacity of her nitrogen fixation plants. The Allies, on the other hand, having control of the seas, continued to depend on the Chilean nitrate beds.

The desirability of the United States becoming self-sustaining in the matter of the supply of nitrates was recognized prior to our entry into the war and in 1916 Congress appropriated $20,000,000 for investigations relating to the fixation of atmospheric nitrogen and for the construction of nitrate plants.

Shortly after the declaration of war the decision was made to erect a small synthetic ammonia plant, using a modified form of the Haber process which has been developed by the General Chemical Company. Construction of this plant, United States Nitrate Plant No. 1, was begun at Sheffield, Alabama, in October, 1917. The plant has a designed capacity of 10,000 tons of anhydrous ammonia per year. One of its units was operated experimentally for several months. A number of difficulties were encountered and the plant was never put on a production basis. As a result of extensive investigations carried on by the Fixed Nitrogen Research Laboratory, it is estimated that the plant could be re-designed so as to operate satisfactorily at a cost of from $3,000,000 to $4,000,000.

The heavy losses to shipping caused by the German submarines in 1917 threatened to reduce the tonnage available for the transportation of nitrate from Chile and made it unsafe for the United States to depend on imported nitrates.

The War Department, therefore, decided on the erection of United States Nitrate Plant No. 2, near Sheffield, Alabama, at the foot of the Muscle Shoals of the Tennessee River. This plant was to have a capacity of 110,000 tons of ammonium nitrate per year, and was to use the cyanamid process. This process was selected largely on account of its dependability. A plant using the same process has been in operation at Niagara Falls, Canada, for several years, and the services of its engineers and chemists were available for the design and operation of the Muscle Shoals Plant.

In 1918, as the menace from the German U-boats was seen to be increasing, work was begun on United States Nitrate Plant No. 3, at Toledo, Ohio, and United States Nitrate Plant No. 4, at Cincinnati, Ohio. These plants were to have a capacity of 55,000 tons of ammonium nitrate each. Neither of them was completed. Operation of the No. 2 plant was begun on October 27, 1918. The plant was continued in operation for a sufficient time after the signing of the armistice to demonstrate that it could be operated successfully.

Within the past two years a small synthetic ammonia plant similar in design to the Sheffield Plant, by taking advantage of the experience gained with that plant, has been put in successful operation by the Nitrogen Products Corporation at Syracuse, New York. The plant has a capacity of 10 tons of anhydrous ammonia per day.

United States Nitrate Plant No. 2

United States Nitrate Plant No. 2, located at Muscle Shoals, Alabama, has a capacity of 220,000 tons of cyanamid, or 110,000 of ammonium nitrate per annum. It is the largest cyanamid plant in the world. It was built by the Air Nitrates Corporation, a corporation organized for the purpose by the American Cyanamid Company. The total cost, including the 60,000 K. W. steam power plant at Muscle Shoals, was approximately $70,000,000. An additional $5,000,000 was expended for a 30,000 K. W. steam power plant on the Warrior River, and a 90-mile transmission line connecting that plant with Muscle Shoals.

The raw materials required are coke, limestone and the nitrogen of the air. When operating at full capacity the plant will consume 300 tons of coke and 1,200 tons of limestone daily. An ample supply of limestone has been provided for at Waco Quarry, 30 miles distant. Coke can be procured in the Birmingham, Alabama, district or from eastern Tennessee.

The power required is 85,000 K. W., and is one of the principal items in the cost of manufacture. Wilson Dam, located one mile east of the plant, will eventually furnish the power. The two steam plants at Muscle Shoals and the Warrior River were erected to supply the power during the war, and until the completion of the dam.

The Products and their Utilization

In deciding to erect the plant during the war, the War Department doubtless had in mind solely the production of ammonium nitrate to be used in making amatol. Certain of its intermediate products, however, may be used for other purposes both military and non-military, and the final product itself may find application as a fertilizer material.

Calcium carbide could, of course, be utilized for the production of acetylene. I have previously mentioned the use

of cyanamid directly in fertilizers, though in small quantities. Recent researches indicate the possibility of converting it into another compound, urea, which is a more satisfactory plant food.

With slight additions to the present plant, the ammonia gas could be converted into ammonium sulphate—a valuable fertilizer material for which there is a ready market.

Nitric acid could be mixed with sulphuric acid and shipped to powder plants and used to make guncotton.

Wilson Dam

The reason for locating the plant at Muscle Shoals was the great power to be obtained by harnessing the waters of the Tennessee River. This river, the fourth in size in the United States, has a flow of from 8,000 to 500,000 cubic feet per second, and a fall of 134 feet in a distance of 37 miles. In the course of years it has cut deep ravines through the limestone rock over which it flows and for miles cliffs 100 feet and more in height line both its banks. Thus it happens that at the foot of the big Muscle Shoals a dam 100 feet high is being built from bank to bank—now known as Wilson Dam—on the Engineer project maps it is known as Dam No. 2. When completed this dam, together with Dam No. 3, which it is proposed to build 17 miles further up-stream, will be one of the world's great water-power developments.

The primary horse-power of Dam No. 2, i. e., the power available for twelve months in the year, is 87,300 H. P. For 97 per cent of the time there will be 100,000 H. P. The power that can be expected for a part of the year only is as follows:

141,000 H. P. for ten months per year.
205,000 H. P. for eight months per year.
306,500 H. P. for six months per year.
600,000 H. P. for 2½ months per year.

At Dam No. 3, the available power will be 40 per cent of that at Dam No. 2.

Work on Wilson Dam was begun, under the direction of the Chief of Engineers, in 1919, and continued until May, 1921, when work was suspended on account of lack of funds.

The amount expended up to that time was approximately $17,000,000. The estimate of the Corps of Engineers of the amount required to complete the Dam and to install eighteen 30,000 H. P. turbines connected to 25,000 K. V. A., 12,000 volt generators, is $28,000,000.

In the Army Appropriation Act of June 30, 1922, Congress appropriated an additional $7,500,000 for continuation of the construction, and work has recently been resumed. It will require probably three years to complete it.

Future Distribution

The developments at Muscle Shoals constitute a tremendous national asset—in time of peace, as well as in time of war. The disposition to be made of the properties is therefore a matter of no little interest.

United States Nitrate Plant No. 2, with a capacity of 40,000 tons of fixed nitrogen per year, is capable of supplying more than one-fourth of the nitrogen used in the United States for the manufacture of military explosives in 1918. It can furnish the nitrogen required to supply twelve infantry divisions with ammunition at the rate at which it was consumed during the World War. It would, therefore, be of tremendous importance in any major war.

It can supply more than a third of the inorganic nitrogen used in the production of fertilizers in this country at the present time. The farmer has, therefore, regarded this plant as an agency for increasing the supply and reducing the price of fertilizer.

The Tennessee River is navigable from its mouth to the foot of Muscle Shoals. The completion of No. 2 Dam and the construction of No. 1 Dam at a cost of $1,400,000 would extend navigation for a distance of fifteen miles. The proposed No. 3 Dam would extend navigation an additional 65 miles.

Traffic on the river is at present very small. To what extent the traffic will grow with these improvements to navigation is problematical.

There is, however, no doubt as to the value of the hydro-electric development at Dam No. 2. In the natural course of development in the region that can be served by Muscle Shoals power, a market can be expected for the primary power of both dams, and the steam plant within a period of from three to six years. Additional time would probably be necessary to develop a market for the secondary power. The operation of the nitrate plant would take an important part of the secondary power and, of course, new industries may be developed to utilize large quantities of power.

A number of offers for the operation of the Muscle Shoals projects have been under consideration by Congress. The offer of Henry Ford has received the widest publicity. Mr. Ford proposes to lease the Dams 2 and 3, with the power plants, for a period of 100 years and to pay 4 per cent on the cost of completion of Dam No. 2, and on the total cost of construction of Dam No. 3. He offers to pay the United States certain fixed amounts annually towards the cost of repair and maintenance of the locks and dams. In addition, he proposes to pay the United States semi-annually for the purpose of building up a sinking fund to return to the United States at the end of the lease period a sum which he estimates, if invested at 4 per cent, will be approximately $49,000,000.

He offers to purchase Nitrates Plants Nos. 1 and 2, including Waco Quarry and the Gorgas Power Plant for $5,000,000. He agrees to operate Nitrate Plant No. 2 at full capacity for the production of fertilizers and to sell it at a profit of not more than 8 per cent. He further agrees to maintain the plant in condition for immediate operation for the manufacture of military explosives.

The Alabama Power Company has submitted an offer to lease the dams under the terms of the Water-Power Act, and as compensation to the United States for the amount already expended at Wilson Dam, will give the United States the first 100,000 H. P. of secondary power.

These offers and others Congress has had under consideration without having reached any decision as to the disposition of the Muscle Shoals projects.

The question as to the disposition of the properties at Muscle Shoals so as to yield the greatest good for the greatest number of people is a most complicated as well as a tremendously important one. The Nitrate Plant must be retained for use in event of war. Its operation in time of peace for the production of fertilizer, if operation can be made economical, would certainly benefit the whole country.

The power from Wilson Dam, whether it is consumed in the immediate vicinity of the shoals, or is distributed over a larger area, is bound to result in industrial development and prosperity in a region rich in natural resources.

Annual Report

of the

Chief of Ordnance, U. S. Army

(The following extract from the Annual Report of the Chief of Ordnance, U. S. Army, for the year 1922, is of considerable interest to the readers of ARMY ORDNANCE, and we are very glad to have the pleasure of printing it in this issue for their benefit.—ED.)

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War Plans

The most important development during the year has been the establishment of thirteen Ordnance Districts, for the purpose of decentralizing procurement and production of Ordnance matériel in the event of a major emergency. These districts are the same as during the World War, except that the territory covered by the St. Louis District has been divided and part assigned to the newly formed San Francisco District. Chiefs have been selected from among the large-caliber progressive business executives for ten of these districts; the remaining three will be selected in the near future. An officer of the Regular Army is assigned to each district chief as executive assistant. There will, in time of peace, be a tentative selection of the personnel of the district organization in the event of war. This war organization will parallel that of the Manufacturing Service of the Office of the Chief of Ordnance.

Classification and storage of retained special facilities, and analysis of the records of munitions production of the plants of the country are being carried on as appropriations permit, in order that comprehensive and detailed plans may be in readiness to use all available resources of the country in the event of a major emergency. As most of the Ordnance matériel required during a war of any magnitude must be manufactured in commercial plants, the cooperation of all manufacturers in plans for industrial preparedness is being urged, in order that every organization and plant in the country may be used to lessen the time and cost of production of the necessary munitions. The cooperation has so far been most encouraging. The business executives still remember many things that might have been done to save time, lives and money, and are anxious to help in order that the maximum effort may be less costly and more quickly exerted. Work is going forward, with their assistance, toward a comprehensive plan of procurement and production that will use the combined experience of the country in the past war in the rapid and efficient production of munitions.

Material

Rifles.—Twenty thousand two hundred and two service rifles were manufactured at the Springfield Armory during the year. Two thousand caliber .22, model of 1922, gallery practice rifles, for the National Board for the Promotion of Rifle Practice, are under manufacture. Twenty-five each of three types of receiver sights for service rifle, recommended for further test by the Infantry Board, have been fitted to service rifles and are now undergoing test at Fort Benning. Investigations are in progress at the Springfield Armory to develop suitable rifle and machine-gun barrels of rust-resisting steel.

Pistols.—Development of the experimental blank firing attachment for the automatic pistol, caliber .45, model of 1911, has progressed to the extent that fifteen such devices have been completed at the Springfield Armory and are now ready for test.

Machine Guns.—Contracts have been placed for fifty-six caliber .50 Browning aircraft machine guns. Plant is now available for the manufacture of five of these guns per day.

Automatic and Semi-Automatic Rifles.—The Browning machine rifle has been approved to replace the Browning automatic rifles now in use in the Cavalry.

Twenty Thompson semi-automatic shoulder rifles have been purchased for field tests. Test of two semi-automatic rifles, of Ordnance Department design, gave sufficiently promising results to warrant further development.

Helmets and Body Armor.—Duraluminum was tested for helmets and body armor, but after firing tests was found to be impracticable.

Small-Arms Ammunition.—A new type of armor-piercing caliber .30 ammunition has been developed and a supply is now being manufactured. A new type of long-range tracer ammunition (both red and white trace) has been developed and is being tested. The most accurate ammunition so far produced in quantity was supplied for use in the National Matches of 1921. Caliber .50 armor-piercing, tracer, and service ammunition is being developed.

Infantry Matériel.—A pilot infantry howitzer carriage, with both 1.8-inch and 2.24-inch howitzers, was tested and showed conclusively that one piece would not meet all Infantry requirements. There is now being designed a 57 millimeter gun, with muzzle velocity of 2,000 f/s, and mortars of 75-millimeter and 2.24-inch caliber, the gun, together with one of the mortars, being expected to meet the requirements. The units will travel on their wheeled carriages, or can be divided into loads of about 75 pounds.

Pack Matériel.—The pilot 75 millimeter pack howitzer matériel, with range of 6,500 yards, completed last year, has been tested by the Ordnance Department and the Field Artillery, and some modifications planned. Development abroad of more powerful matériel has led to a study of matériel capable of a velocity of 1,250 foot seconds, and a range of 900 yards.

Divisional Artillery.—Two models of 75 millimeter gun and 105 millimeter howitzer matériel have been under test. Both give a gun range of 15,000 yards and a howitzer range of 12,000 yards. One model has a split trail permitting maximum elevation of 80 degrees and traverse of 30 degrees, with weight, in firing position, of 3,660 pounds. In order to reduce this weight, a gun carriage, giving elevation and traverse of 45 degrees, is now being considered. The other model, with box trail, and a weight, in firing position, of 2,733 pounds, has required some redesign, but is quite promising, due to its simplicity and light weight.

No decision as to a type is expected until the completion of further studies and possibly a pilot of lighter weight split trail carriage. At this time it appears that identical carriages for gun and howitzer are impracticable.

Corps Artillery.—The 4.7-inch gun and 155-millimeter howitzer matériel of Westervelt Board characteristics has been completed, but, due to weakness of the top carriage, will require further study. This carriage provides for a traverse of 60 degrees and 65 degrees elevation. The gun

range is 20,000 yards; the howitzer range, 16,000 yards. The weight, in the firing position, of 13,000 pounds, is more than was desired, but was necessary to give the required range for the howitzer. A lighter carriage, giving 45 degrees elevation, is now being built for the gun. A wagon is provided to transport either gun or howitzer independently of its carriage.

Army Artillery.—Wheeled matériel for a 155-millimeter gun, with a range of 25,000 yards, and an 8-inch howitzer, with a range of 18,000 yards, has been completed and is now under test. The carriage permits of 65 degrees elevation and 60 degrees traverse, and weighs, in the firing position, approximately 24,000 pounds. A transport wagon for the gun or howitzer is provided.

Trench Mortar Matériel.—A pilot 155-millimeter trench mortar has been completed and tested. The mortar uses a 50-pound projectile, with a range of 4,000 yards. The carriage, which can be transported on its own wheels or divided into small loads for hand transportation, developed certain weakness, and redesign is under way.

Anti-Aircraft Artillery.—Pilot 3-inch and 4.7-inch anti-aircraft guns have been completed and are undergoing test. Both guns have a velocity of 2,600 f/s, and are mounted on carriages permitting all-around fire and an elevation of 80 degrees. Mechanical devices have been provided for loading and for ballistic corrections in direct fire. The 3-inch gun is being tested on a trailer mount; the 4.7-inch gun on a self-propelled mount.

Fire Control.—Much study has been given to fire-control instruments for seacoast and anti-aircraft artillery, in connection with which a system has been developed for the automatic transmission of data from the observing stations and the automatic prediction of target position and correction of fire. Some of the instruments have been tested, while others will be submitted for test at an early date.

A gyroscopic instrument for use in balloons has been completed and is undergoing test. Other instruments for observation from the air are in course of development.

For anti-aircraft firing a central station apparatus, which will predict the position of the plane and make necessary correction of fire, is under development. Attention is also being given the development of instruments for use in airplanes in observing field-gun fire. Internal-base range finders are being studied to improve their accuracy.

Aircraft Gun Matériel.—Some 37-millimeter motor guns are being redesigned for use on mountings as free guns. The mechanism of these guns is semi-automatic only. Air Service requirements call for a full automatic gun with a maximum weight of 125 pounds and a muzzle velocity of 2,000 f/s, and work is being carried on to develop such a gun. Attempt has been made to interest civilian designers in this work.

Sixteen-inch Matériel.—The 16-inch gun and the 16-inch howitzer matériel has been proof-fired. The gun matériel represents a marked advance in seacoast artillery. The carriages permit the firing of 50-caliber guns at all angles of elevation from minus 7 to plus 65 degrees. Future carriages will be modified to use 16-inch naval guns. Test of the 16-inch disappearing carriage, mounting a 50-caliber gun and giving a maximum elevation of 30 degrees, has been successfully completed, and the matériel is being prepared for shipment to destination.

Fourteen-inch Railway Matériel.—Development work on the 14-inch railway program is proceeding. This matériel mounts 14-inch, 50-caliber guns, fired either from a track or small turn-table, having power sufficient to penetrate battleship armor at considerable range, and offers great possibilities in coast defense, due to its great mobility and the comparatively short time required to emplace it.

Divisional Motor Carriages.—Pilots of both the track-laying and the combined wheel and track-laying types have been under test throughout the year. When these carriages were designed it was considered that a speed of from 25 to 30 miles an hour should be secured. The power requirements for such speed necessitated large engines, which, in turn, demanded heavier construction throughout, resulting in greater weight of vehicle than is considered desirable. Tests indicate that there is no necessity for such extreme speed; also that high speed with the present design of caterpillar vehicles is impracticable, as it entails almost prohibitive maintenance.

The waterproofing of the power plant by means of covers over the spark plugs, magneto, etc., has been found impracticable. The addition of these parts interferes with adjustment and repair of the engine and after running several hundred miles on hard roads it was invariably found that the waterproofing had become ineffective.

As a result of tests, it is considered that divisional motor carriages, of light weight and moderate speed, are thoroughly practicable and that they can be made dependable, with motors readily accessible for adjustment and repair.

Corps Motor Carriage.—The design of a corps motor carriage mounting, interchangeably, either the 4.7-inch gun or the 155-millimeter howitzer, has been completed and manufacture of a pilot inaugurated. Every effort has been made to eliminate weight. The estimated weight of the completely assembled unit is 20,000 pounds, which compares favorably with the corresponding wheeled carriage weighing 14,500 pounds, and a 15,000-pound tractor. The characteristic features of this design are a fully sprung body, equalized and jointed truck frames to facilitate rough cross-country maneuvering, and the employment of rubber in the track and track-supporting rollers and on the drive sprockets and front idlers, in order to absorb shock and eliminate vibration. The maximum speed is 18 miles an hour.

Army Motor Carriage.—A battery of 155-millimeter G. P. F. motor carriages of the combined wheel and track-laying type has been given a service test by a brigade of Coast Artillery at Camp Jackson. As a result of the test, and to correct several defects which developed, one of the carriages was rebuilt and is now under test at the Aberdeen Proving Ground.

Two new pilot motor carriages, of the track-laying type, which will mount, interchangeably, the new 8-inch howitzer and 155-millimeter gun, have been completed and are being assembled for test. The engine, with the 6 cylinders in line, is inclined at 45 degrees to give lower over-all height. Six speeds forward and two reverse are operated through a control box and steering post. Speeds varying from 1 mile per hour, over difficult roads, to 14 miles per hour on good roads, are obtainable. Elevation of 65, and traverse of 10 degrees of the gun on the carriage are provided, and movement of the entire carriage readily permits a field of fire of 360 degrees. The height of the axis of the gun is only 65 inches, eliminating the necessity for a loading platform.

Tractors.—With the exception of rebuilding the two pilot models of 2½-ton tractors (Divisional, Model of 1920), the activities of the Ordnance Department in the development of special military tractors have been confined almost entirely to the continuation of the construction and test of those pilots of divisional, corps, and army types, the design of which was initiated after the World War. The selection of improved types of artillery tractors is not, however, being confined to the development of vehicles of special construction intended primarily for military use, as the Ordnance Department is keenly alive to

the advantages which would be gained by adopting a commercial type which is produced in quantity in time of peace. With this end in view the industrial field is being canvassed to determine which types give most proimse of meeting military requirements in tractors.

Trailers.—As in the case of tractors, the work of the Department during the year on the development of trailers has been confined almost entirely to the test of pilot vehicles the design and construction of which were undertaken shortly after the Armistice. Necessity for the development of track-laying trailers arises from the motorization of artillery in which, for the transportation of ammunition, the present wheeled limbers and caissons are unsuitable; running gears of the track-laying type are therefore being incorporated in all designs of Ordnance trailers. For the transportation of divisional artillery ammunition, there have been designed and constructed three types of trailers weighing approximately 1½ tons, with carrying capacity equal to their weight. For the transportation of ammunition for corps artillery two pilot models of trailers of 3-ton capacity have been constructed. A smaller trailer, of ¾-ton capacity, designed primarily for Infantry use, has been constructed and tested.

Infantry Power Cart.—One point very clearly demonstrated during the World War was the failure of horse-drawn vehicles in cross-country work. Consequently, there is urgent demand for the replacement of horse-drawn vehicles by motor vehicles for use in transporting small-arms ammunition, machine guns, trench mortars and similar matériel into position for use, usually far removed from good roads. In this scheme of development there have been designed two types of power carts—one of 600, and the other of 900 pounds weight. The characteristic feature of these vehicles is a cargo body supported on running gear of the track-laying type, which is motor-propelled and normally operated by a man walking in rear of the vehicle. Construction of the two pilots is under way and it is expected that tests will take place in the fall of 1922.

Infantry Hand Cart.—To relieve the soldier in the transportation of such matériel as machine guns, trench mortars and their ammunition, etc., near the scene of action and over ground unsuited to motor transportation, there are being developed two small two-wheeled carts, to be hauled by one or two men. Extreme lightness of construction is the characteristic of this design. The wheels are of standard bicycle type, with pneumatic tires, and the vehicle frame is constructed of aluminum alloy. Two pilot models have been completed and after preliminary proving ground test, will be shipped to Fort Benning for test by the Infantry.

Motorcycle.—The value of the motorcycle for messenger and scout work is well known, but it is limited by its inability to cross swampy or extremely rugged country. There has recently been constructed a fabric track of the Chase type which, with slight modication in a commercial motorcycle, can be placed around the front and rear wheels, reducing the bearing pressure on the ground and enhancing its value as a cross-country vehicle. Tests of a motorcycle so equipped are now under way.

Similar experimental work has been undertaken on light trucks. A Dodge car, of the six-wheel type, has been equipped with fabric track; has been tested at the Aberdeen Proving Ground, and will shortly be shipped to Fort Benning for test by the Infantry.

Tanks.—The Ordnance Department has conducted a large amount of tank development work during the past year, including the manufacture and inauguration of tests of three new experimental medium tanks. At the present time, first consideration is being given to perfecting the development of the medium-weight fighting tank. In the design of this tank it is proposed to incorporate all of the maneuvering ability possessed by the light tank on rough terrain, together with the superior armament advantages of the heavy tank, and armor sufficient to afford protection against small-arms and machine-gun bullets. When the medium tank with its effective armament, armor protection, speeds and weights, together with arrangements for vision, intercommunication and protection against gas shall have finally been developed, it promises to be an excellent fighting tank, capable of accompanying the Infantry at all times.

Of the three experimental medium tanks recently completed, two are of Ordnance design, and the third, of the combined wheel and track-laying type, was designed by the Front Drive Motor Company, of Hoboken, N. J. The Ordnance tanks were designed in collaboration with the Infantry Service. Their armament consists of one 6-pdr. cannon and two machine guns, mounted in two superimposed independently revolving turrets, affording a 360 degree field of fire. The third tank, designed and built by the Front Drive Motor Company, embodied Mr. Walter Christie's patented feature of a combined wheel and track-laying type. This feature is being tested out on a number of motor carriages, and a tank of this type was constructed and placed under test to determine whether or not his convertible type of vehicle would be of value for fighting tanks.

To provide satisfactory all-round vision for tank commanders, a stroboscope has been developed which, under preliminary test, has given very satisfactory results. A satisfactory system of intercommunication has been developed and tested, and is now being installed in the Mark VIII tanks in service. Both magnetic and gyroscopic compasses for tanks have been developed and are now undergoing test.

While it may be said that satisfactory progress has been made in tank design since the Armistice, the tank is a very special vehicle, of exceedingly difficult design, and a large amount of development work still remains to be done before thoroughly practical types, fully meeting all requirements of the service, can be produced.

Ammunition

Propelling Charges.—A new method for reworking smokeless powder has been designed and developed and is now under test. If successful, this method will eliminate the more expensive grinding operation. A new method of air-drying smokeless powder has been designed and is now in the stage of development. Satisfactory progress has been made during the year in the development of smokeless, flashless, non-hygroscopic powder; this work was carried on simultaneously at the Picatinny Arsenal and by the E. I. du Pont de Nemours Company, but along different lines. Experimental lots were produced and tested. Test in a 75-millimeter gun gave satisfactory ballistics, scarcely perceptible flash, but somewhat greater smoke than the standard service powder. Development work is proceeding and further tests will be made.

The work of balancing propelling charges for seacoast ammunition has been continued during the year. In view of the satisfactory results obtained by this method, all old powders are carefully blended before being made up into charges. Charges made up under the aliquot part plan for the 155-millimeter matériel were issued to the Field Artillery for test; similarly made up charges for 12-inch mortar were issued to the Coast Artillery. Reports of these tests have not yet been received.

Primers.—A new 100-grain primer has been designed, de-

veloped and tested with satisfactory results. This primer has a decided advantage over the 49-grain primer for use with flashless powder in the 75-millimeter gun, as well as with ordinary smokeless powder.

A new explosive for bursting charge for armor-piercing projectiles is being investigated. Results thus far obtained indicate it to be stronger and less sensitive than Explosive "D."

Fuzes and Detonators.—A satisfactory fuze for seacoast projectiles has been designed, developed and tested. Production orders have been placed.

Work on point-detonating fuzes, to meet modern field artillery requirements, has continued during the year. Fuzes of the super-quick and short-delay types have been designed, developed and tested. Results of tests show that further development work is required.

A base-detonating fuze for small caliber armor-piercing projectiles has been designed and developed for use in tank and anti-aircraft guns. However, further development is necessary for the satisfactory functioning of this fuze against armor plate.

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Mobile Artillery Projectiles.—The production of common steel projectiles during the year has been limited to new types for test and experimental purposes. Changes have been made in the shape of the 75-millimeter and 105-millimeter projectiles, and tests conducted gave satisfactory results with the former; results with the latter, however, at maximum elevation, were not altogether satisfactory.

Railway and Seacoast Projectiles.—The production of armor-piercing projectiles was limited to small quantities for test and experiment. Large quantities of 14-inch and 16-inch projectiles were received from the Navy. In accordance with the War Department policy, the practice of loading projectiles at seacoast defenses has been discontinued and such loading is now done at the arsenals.

Grenades.—Effort is being made to develop a discharger which will throw both grenades and pyrotechnics; this has resulted in the temporary suspension of work on rifle grenades. Grenades for training and practice purposes were manufactured and issued to the service.

Bombs.—Manufacture of an experimental lot of 4,000-pound demolition bombs has been completed and tests now in progress indicate that this bomb will be equally as satisfactory as was the 2,000-pound bomb used during the maneuvers of 1921. Development tests of modified types of 100-, 300- and 600-pound demolition bombs and a new type of 1,100-pound demolition bomb have been completed and the types approved by the War Department for issue to the service. Development tests of new types of 100-, 300- and 600-pound demolition and of fragmentation bombs are in progress for the purpose of establishing basic designs for this matériel. Extensive development tests of incendiary and smoke bombs have been undertaken in cooperation with the Chemical Warfare Service and the Air Service. In addition to the usual proving ground tests, tests were conducted, in September, 1921, against the battleship *Alabama*, using incendiary, smoke, gas, and demolition bombs. The 2,000-pound demolition bomb repeated its success in previous maneuvers by sinking the *Alabama* in less than one minute.

Research and Ballistics

Research Work.—Considerable research work has been carried on in the development of gun steels, in the study of internal strains in steels, on the impact test of steels, and the effect of phosphorous and sulphur in steels. Metallurgical programs are coordinated with other research agencies. For the continuation of research work on steels a powerful X-ray apparatus has been installed at the Watertown Arsenal and will be put in operation at an early date. With this apparatus it will be possible to investigate physical defects in pieces of steel of a thickness up to three inches, and to carry on research work on the atomic structure of steels and the effect of internal stresses on such structures.

Gun Construction.—Work on the auto-frettage process of gun construction has been carried on during the year and a 155-millimeter howitzer modified by this process is now awaiting test. Hollow cylinders are also being subjected to internal hydraulic pressures which stresses them within and beyond the elastic limit. By means of this work it is hoped to determine more closely the laws underlying the auto-frettage process of gun construction.

Owing to the lessened demand for high-grade ordnance steels, as a result of the recent Conference on the Limitation of Armaments, it is considered necessary to abandon temporarily the results obtained by the use of higher grade gun steels and to fall back to the pre-war specifications for gun steels. The gun designer is thus limited by the producing capacity of the country, rather than by the possibilities of steel development.

Standardization Work.—The Ordnance Department is cooperating with the Federal Specifications Board, with the American Engineering Standards Committee and other organizations of the country in the standardization of metal specifications and in the establishment of standards of design. Attention is also being given to the standardization of minor parts, such as bolts, nuts, etc., making them conform as closely as practicable to those commonly used in commercial practice. This will greatly facilitate quantity production in case of sudden emergency.

Air Resistance.—The experiments in air resistance being conducted at the works of the General Electric Company, Lynn, Mass., by Dr. G. F. Hull in a consulting capacity, for the Ordnance Department, have been continued during the year, although the number of experiments have necessarily been limited. Additional data have been secured upon the resistance of projectiles inclined to the direction of the air stream and upon the resistance of bomb forms.

Ballistics.—Work on the interior ballistic experiments on a 240-millimeter howitzer has been inaugurated and excellent results are being obtained in the measurement of times and pressures along the bore. It is anticipated that this program will continue for at least another year.

The piezo-electric time-pressure gauge has, with the assistance of the Bureau of Standards, been developed to the point where results are obtained with certainty. This gauge is being used in connection with the 240-millimeter howitzer experiments, and its calibration under conditions of firing remains to be determined by comparison with other methods of measuring interior pressures.

The study of ballistic characteristics of bombs has been continued. Valuable results have been obtained in tests of bomb models in the low velocity wind tunnel at the Bureau of Standards and in the high velocity wind tunnel at Lynn, Mass. Installation at the Bureau of Standards of a low velocity wind tunnel for testing full-size bombs has been completed and tests are now in progress. Installation of camera obscura equipment at the Aberdeen Proving Ground is approaching completion. This equipment will be used in obtaining ballistic data on actual bombs and full scale models and will permit the dropping of bombs at all altitudes up to 20,000 feet.

Range Tables.—A large number of range tables and other similar data, for weapons of all calibers, including small

arms, have been completed during the year. There have also been published a number of very important papers dealing with ballistics and related subjects.

Supply and Maintenance

During the past year the duties and the responsibilities of the Ordnance Department in reference to the care and maintenance of matériel committed to its charge have not been materially lessened. Rather, the disbandment of Regular Army personnel, and the evacuation of camps and other stations, have resulted in turning over to the Department for care, repair and storage a large amount of matériel, entailing an unusual quantity of work. The Department has met the additional demands thus made upon it and has placed the matériel in permanent or semi-permanent storage and at the same time has been enabled to make material reductions in the personnel engaged and the funds required.

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Supply.—The Ordnance items of general supply on hand at the close of the year, with but few exceptions, are considered ample for present needs. By means of the Ordnance Provision System the Ordnance Office at Washington is constantly informed of the status of stocks in all Ordnance depots. This system provides a running inventory with reports of the same rendered periodically to the office where the consolidated records are maintained. During the year the method of supplying troops has been decentralized by causing most of the work in connection therewith to be carried on by the corps area ordnance officers. There has been considerable activity in equipping newly formed National Guard units.

Large quantities of arms and ammunition have been issued to the Post Office Department and some to the Bureau of Internal Revenue, Treasury Department, in accordance with the provisions of existing law.

Incident to the abandonment of several large camps, much Ordnance matériel has been moved to permanent storage. Lack of funds to cover transportation costs, however, has seriously interfered with the progress of this work, and has necessitated storage at these abandoned camps, or shipment to the nearest permanent establishment, of much valuable Ordnance matériel. Efficiency and economy demand that funds should be made available to transfer this equipment to permanent storage. This will obviate the maintenance of special organizations and extra handling and shipment that will ultimately considerably increase the cost of the work.

Distribution of captured enemy war devices and trophies cannot be begun, due to absence of necessary legislation. Proper storage space is not available for this matériel and most of it is rapidly deteriorating.

Ammunition Supply.—In carrying out the storage, maintenance and issue of ammunition and its components to the Regular Army, National Guard organizations, rifle clubs, etc., many difficulties arose due to the fact that large quantities of this matériel were found to have deteriorated from exposure owing to improper packing, etc., incident to war-time conditions. In many instances it was not possible to provide proper storage for this matériel due to the congested condition at most of the permanent Ordnance depots. The work of overhauling, re-arranging and placing this matériel in condition for permanent storage has, therefore, formed an important part of the work of the Department during the year. All mobile-artillery and small-arms ammunition in service has been located by lot number, and representative samples of each lot have been shipped to Aberdeen Proving Ground and Frankford Arsenal, respectively, for proof-firing tests to determine suitability for issue and the effects of storage. In connection with the results of these tests record has been established showing existing conditions and classification of each lot, which information is deemed of great importance.

Maintenance.—The principal operations of the Ordnance Department in connection with the maintenance of matériel in the hands of troops and in storage may be summarized as follows:

For maintenance of matériel in the hands of the Regular Army, the sum of $585,045 was allotted to ordnance officers in the field. This matériel has been maintained in satisfactory condition, the work having been performed by the personnel of Ordnance (Maintenance) Companies and Ordnance detachments, assisted by civilian mechanics. Maintenance personnel for the summer training camps was provided from personnel already on duty in the field and from Ordnance (Maintenance) Companies stationed at manufacturing arsenals.

For the maintenance of Ordnance matériel in storage at Ordnance establishments, the sum of $265,675 was allotted during the year. The value of this matériel, not including ammunition, is approximately $500,000,000.

The sum of $485,645 was allotted during the year for the procurement of spare parts, and effort has been made to balance the stock of spare parts on hand. It is planned to continue the procurement of spare parts until at least one year's supply shall be on hand. This will permit prompt issue of parts as required by the Service.

Modifications and Overhaul.—A system for issuing modification work orders has been perfected during the year and 95 such orders were issued. This work is being prosecuted in order that all Ordnance matériel may be modernized to conform to the approved revisions. Large quantities of Ordnance matériel requiring overhaul were on hand at Ordnance establishments at the beginning of the year. During the year, the sum of $528,446 was expended in the overhaul of small-arms matériel which included 73,700 weapons. The amount expended in the overhaul of automatic rifle matériel during the year was $46,981. This included 2,994 automatic rifles and 4,925 machine guns. For overhaul of mobile-artillery matériel, comprising 2,253 guns and carriages, 3,642 accessory vehicles and 30,224 pieces of fire-control equipment, the sum of $409,000 was expended. Automotive matériel, including 634 tractors, 222 trucks and 73 trailers, was overhauled at a total cost of $214,830.

Salvage

Although much less than in previous years, the amount of Ordnance property declared surplus and disposed of by sale and transfer during the year was considerable. The total contract price of all sales made during the year was in excess of $12,500,000. Moreover, there was no reduction in the volume of sales toward the close of the year (the receipts from sales for May and June, respectively, were in excess of $1,000,000). In a large part this is due to additional declarations of surplus ammunition resulting from the reduction of the War Reserve.

The largest single item offered for sale was sodium nitrate, of which 100,000 gross tons were sold for a total of approximately $3,800,000. Loaded ammunition of a cost value of $20,000,000 was turned over to the contractor to be broken up and salvaged. The amount received by the United States for this ammunition was approximately $500,000. Other important sales included shell and shell forgings, brass cartridge cases, machinery for the manufacture of guns and shell, armor plate, and special parts for tanks.

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The German Ammunition Problem in 1914

By

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NUMEROUS studies have been made in the last few years of the American ammunition problem. The most thorough study was that of the Munitions Board, which was appointed in 1919 to fix definitely the amounts of ammunition in the various calibres that should be held as a special war reserve to meet the needs of this country in case of war until new ammunition resulting from war contracts could reach the front. The Munitions Board made a very complete study of the problem and fixed a minimum amount of ammunition in each calibre that should be retained as a war reserve. In addition where a surplus stock of ammunition was on hand, they fixed an amount which should be held to meet current requirements during the probable life of the ammunition.

In general, previous studies of this question have been based on the experience of the American and of the Allied armies during the latter years of the World War. During this period the fighting was mainly from fixed positions and the rate of fire per gun was very high. In marked contrast to this high rate was the expenditure of ammunition during the year 1914. Accurate figures are now available as to the amount of ammunition on hand with the German army at the outbreak of the war. These figures were recently obtained from a study of the confidential archives by Lieut. Col. Krueger, of the General Staff.

On January 6, 1912, General Von Moltke, Chief of the General Staff of the German Army, fixed the war reserve of the field artillery ammunition at 1,200 rounds per gun, and wrote to the Ministry of War on that date as follows: "I can only welcome the intention of the War Ministry to continue the development of the ammunition reserve of the field artillery to such a point that for every single gun there will be a total of 1,200 rounds available. The figure of 1,200 rounds seems to me absolutely necessary in view of the small amount of ammunition which, as I now hear, and in spite of all our efforts, can be manufactured after the proclamation of mobilization, I must ask that that figure be reached as soon as possible."

General Von Moltke did not neglect the needs of the heavy artillery. On October 11, 1911, the following memorandum was sent to the War Ministry; "I have always realized that the heavy artillery of the field army is in a better position than the field artillery, though it is not as good as I had assumed * * * If we draw on the stocks of the siege artillery, including the supplies of the fortresses there will certainly be no shortage of ammunition for the heavy artillery of the field army. But there will still be the question how, with the supply of ammunition available, we shall be able simultaneously to carry on sieges, the rapid conclusion of which must also be the object of speedy operations." It is apparent that in the early days of the war the German army did draw on the reserve ammunition supplies of the fortresses, especially those located on the western frontier, for we note that the ammunition expenditures for the heavy calibres in 1914 did not exceed the reserve stock on hand at the beginning of the war. A single exception is the 21-centimeter howitzer, which expended slightly more than the reserve stock, due probably to the large scale on which this weapon was employed in reducing the Belgian and French frontier fortresses.

On August 1, 1914, at the outbreak of war, the German army had the following supply of guns and ammunition available for use in the field:

	77 mm. gun	105 mm. L how.	150 mm. H how.	10 cm. gun	21 cm. H how.
Guns	5,068	1,260	1,368	192	216
Total rounds	3,864,000	954,000	1,596,000	814,000	199,000
Rounds per gun	762	757	1,166	4,239	921

In addition to the above a total of 21 howitzers of the calibres 28 centimeter, 30 centimeter, and 42 centimeter were available for use in the field as well as 40 of the 13 centimeter guns. It is evident that the German army fell considerably short of acquiring the reserve of 1,200 rounds per gun for the field artillery armament. The rounds per gun for calibres above the 105 millimeter Light howitzer are somewhat misleading, as the number of guns shown are those that were actually available for use with the armies in the field. A considerable number of the larger guns were emplaced in permanent fortifications and so all of the ammunition for these calibres was not actually available for use in the field as is shown in the table.

The monthly deliveries of artillery ammunition of the principal types provided for by the Germans for 1914 were as follows:

Two hundred thousand rounds for the 77 millimeter gun.

Seventy thousand rounds for the 105 millimeter Light howitzer.

Sixty thousand rounds for the 150 millimeter Heavy howitzer.

One hundred and twenty-five thousand rounds for the 21 centimeter howitzer.

Under the terms of the contracts made for the manufacture of the above ammunition deliveries were to start in from four to seven weeks, the full monthly deliveries to be reached by the sixteenth week after the first mobilization day.

The monthly expenditures by the Germans of field-gun ammunition from 1914 to 1918 were:

Year	Expenditure of Ammunition		Number of Guns	
	77 mm. guns	105 mm. how.	Field Arty.	Heavy Arty.
1914	1,075,000	144,000	6,780 (August 1, 1914)	2,632
1915	1,424,640	540,000		
1916	2,903,040	1,152,000	8,614 (August 1, 1916)	6,169
1917	3,575,040	1,620,000	10,930 (August 1, 1917)	6,525
1918	5,376,000	2,484,000		

The increase shown above is of course partly due to the

increasing number of guns used. Attention is specially invited to the greater jump in the expenditure of the 105 millimeter howitzer as compared with the increase in the expenditure of ammunition for the 77 millimeter gun. This clearly shows the present need and importance of a light field howitzer of this approximate calibre.

A complete tabulation of the amount of ammunition for the principal types that was delivered to and expended by the German army each year during the World War is shown below. In 1914 the rate of fire for the 77 millimeter gun was approximately seven and one-half rounds per day. The French army reported a daily rate of fire in 1914 for the 75 millimeter gun of about eight rounds per day. This daily rate of fire rapidly increased as the warfare became stabilized until in active sectors in 1918 the rate of fire per gun became as high as sixty rounds each day.

	77 mm. Field Gun Amm. Rounds		105 mm. Light Field Howitzer Amm. Rounds	
Reserve on hand, August, 1914	3,864,000		954,000	
	Delivered Rounds	Expended Rounds	Delivered Rounds	Expended Rounds
1914	3,299,520	5,496,960	1,200,000	1,728,000
1915	22,061,040	17,109,120	8,247,000	6,519,000
1916	35,105,230	34,870,080	14,205,000	13,830,000
1917	47,429,760	43,270,800	21,501,000	19,665,000
1918	55,009,920	55,480,320	23,118,000	24,849,000

150 mm. Heavy Field Howitzer Amm. Rounds 1,596,000		10 cm. Gun Ammunition Rounds 814,000		21 cm. Heavy How. Ammunition Rounds 199,000	
Delivered Rounds	Expended Rounds	Delivered Rounds	Expended Rounds	Delivered Rounds	Expended Rounds
235,500	1,437,000	32,500	561,000	41,000	217,000
6,220,500	4,695,000	1,191,700	850,500	836,000	634,000
12,101,000	10,786,500	2,352,000	2,381,000	1,957,000	1,937,000
14,248,500	12,618,000	5,317,000	4,612,000	2,293,500	2,145,000
11,350,500	12,195,000	5,242,000	5,263,000	2,451,500	2,377,000

What is an Ordnance Officer

By

R. R. NIX
Member, A. O. A.

[This article is presented as the views of an individual. It does not attempt to set forth the policy of the Chief of Ordnance.—Ed.]

At least ten officers of ten years' or more service in the Ordnance Department were recently asked, "What is an Ordnance Officer?" and as many different answers were obtained. Certainly there existed no generally accepted definition of this particular individual and yet each and every reply was correct. True, the extemporaneous answers were dictated in no small measure by the distinctive qualifications of the officers interrogated: a construction, production, or industrial engineer, a specialist on ordnance matériel, a proving ground expert, an able executive and so on to more than ten varieties.

The following exposition is submitted without pretense of attempting an official definition, but with a purpose to visualize a definite goal and to indicate the means of attaining that goal. This purpose will be highly served if but a few officers derive help from these remarks in planning their future work and their preference for stations to the end that they may be detailed, consistent with exigencies of the service, on such duties as will give them the largest opportunities to qualify most speedily as Ordnance Officers. It is hoped, moreover, if the writer's perspective be narrow and foreshortened that a voice of free criticism may be heard from other readers of Army Ordnance, particularly those who served as Ordnance Officers during the World War. For, after all, the goal to be outlined lies permanently in the zone of battle efficiency.

In general terms an Ordnance Officer is an officer qualified to serve the Ordnance Department effectively in accomplishing its mission. This mission is to be *prepared always* to serve the Line of the Army with satisfactory munitions at the minimum equal in quality and quantity to those available to a probable enemy. Predicated upon this mission the four principal activities of the Department are, broadly speaking, development, procurement, manufacture, and supply. An officer who has satisfactorily developed along any one of these programs fills a limited but necessary function as a specialist, but if he is to compass the broader requirements of an Ordnance Officer he should have a certain amount of training along each and all of these separate lines.

Taking up these programs in order, our design and development work is carried on in the Ordnance Office, at Arsenals and at Proving Grounds. While a technical education similar to Course I in Ordnance Engineering now conducted by the Ordnance School at the Massachusetts Institute of Technology is very desirable as a preliminary training for all officers engaged in Ordnance design or procurement, it is by no means essential. An Ordnance Officer is not necessarily an Ordnance or Construction Engineer. The man gifted with special facility for handling differential equations or mathematically expert in the resolution of forces may not always be exact or conclusive in analysis and may require an officer of broader experience and sounder judgment to supervise his work. Again, an officer who has not been engaged on design or the study of engineering for a number of years may not be able to adapt himself with the required degree of facility to an Ordnance Engineering course; this is not sufficient reason to eliminate him as an Ordnance Officer. On the other hand an expert on design, on matériel, on metallurgy, optics, chemistry, electricity, mechanics, steel making or ballistics may become a better Ordnance Officer because of the very fact that he is a specialist. Wherever it can be arranged the officer possessing these desirable qualifications should take advantage of a postgraduate course now provided at the M. I. T. or at the University of Chicago, or other educational institution, or a detail at a large industrial plant. At all events an Ordnance Officer should be well informed on technical Ordnance subjects in order that he may be competent to direct the efforts of experts and specialists.

No experience benefits him more in this regard than service at a Proving Ground; service in the Ordnance Office and at Arsenals will be referred to later. It is not claimed that service at a Proving Ground provides the same fundamental engineering instruction as that secured at the Ordnance Schools, but indeed it does furnish an excellent training whereby an officer may assimilate the practical application of basic principles of Ordnance Engineering; and it does enable an officer to study the latest development in matériel and to become familiar with the design, operation and use of a greater variety of munitions than he will likely have the opportunity to investigate at any one station elsewhere. It appears that every officer who has not had a scientific and engineering course equivalent to that pursued

at Ordnance Schools should, as soon as practicable, have a tour of duty at the Aberdeen Proving Ground; it further appears that graduates of the Ordnance School, whenever possible, should obtain proving ground experience, supplementing theoretical studies with practical application.

The second subject, that of Procurement, involves the problem of industrial mobilization and the obtaining of probably more than 95 per cent of all ordnance from commercial establishments in time of war. The synchronization and coordination of industrial plants which will furnish this great bulk of ordnance requirements devolves upon the Ordnance Department and is one of its most important lines of endeavor. For this purpose thirteen ordnance districts are now being organized on a peace basis, similar to those which functioned during the World War. This intimate contact with the industrial pulse of the Nation is no less imperative for our Ordnance personnel than direct contact with the Line of the Army. While a tour of duty at one of the principal manufacturing arsenals, and more preferable still the command of an Ordnance Depot or larger establishment, or a detail at a large industrial plant, will give the zealous officer an opportunity to become familiar with the industrial activities of the district in which the plant is located, and while experience may be gained in this capacity in administration, organization, working conditions fostering steady employment and good will, best practice in surveying production, methods of finance, specifications for design, manufacture and inspection, contracts and property accounting, it is believed that every officer who has not had the full equivalent of this education should round off his experience by actual service in an Ordnance District.

Intimately associated with the problems of procurement are the war plans of the Army. Officers selected for these very important duties in Washington or as students at the General Service Schools at Fort Leavenworth and at the Army War College should accept such details eagerly, because not all Ordnance Officers can hope to be so fortunate. Likewise, details as student officers to the special service schools conducted by line branches and the detail as Ordnance representative on a Line Board, such as the Coast Artillery Board, are not less beneficial to the officers selected than to the Ordnance Department and the Army as a whole.

Another new field which like the District Organization brings the Ordnance Officer into needful contact with civilians, and has assumed the importance it deserves as a result of the World War, is the recruiting and training of the Reserve Corps. A detail on R. O. T. C. duty at a college or in camp, or duty in connection with the Organized Reserve will prove most instructive and beneficial, and like the subject discussed in the foregoing paragraph, will result in further benefit to the Ordnance Department and to the Army as a whole. But as far as the individual officer is concerned this full experience is not considered essential to his qualifications as an Ordnance Officer.

Familiarity with the third requirement, involved in the program of Manufacture, and including business methods, construction of plants, operation, fabrication and inspection, may be gained by intelligent service at an arsenal. At the Watertown Arsenal, in the Ordnance School, student officers are given a year's excellent instruction, Course II, in practical shop work so that they may be better prepared to handle production problems at arsenals. Not every Ordnance Officer requires this course any more than it is necessary for every Ordnance Officer to be a production engineer. Yet the equivalent of such a course is essential and can be gained by proper diligence during a tour of duty at a manufacturing arsenal. In fact some of our superior Ordnance Officers have never attended Ordnance Schools; however, these men are invariably good students and have taken full advantage of the opportunities presented them. Officers possessing special qualifications for manufacturing work, and so desiring, should endeavor to be detailed to a large industrial plant and avail themselves of the course in Administration and System of Management at the Watertown Arsenal.

Even though an officer be a designing and production engineer, even though he be an expert on procurement, he still lacks the ultimate qualification toward which in truth all his training should focus, the efficient supply of munitions to troops. Whereas Ordnance Officers serving in the United States during the World War were continually exercising their engineering or administrative talent, skill, and ability, those serving in France were engaged principally with the problem of supply.

The Ordnance Field Service is that branch of our Department which vitalizes this service, demanding a direct knowledge of the munition needs and troubles of troops and the ability to meet these needs promptly and efficiently. So important is this duty considered by the War Department that Ordnance Officers are required to serve one year of every five with troops. Until an officer has been detailed on work of this nature for a year as corps, division, department, camp or post ordnance officer, his training is incomplete.

From the above considerations it follows that an officer should have the equivalent of the following education, experience and training in order to carry on effectively the mission of the Ordnance Department:

(1) Theoretical Course I in Ordnance Engineering at the Ordnance School, or equivalent training.

(2) Practical Course II in Shop Practice at the Ordnance School, Watertown Arsenal, or extended duty at a manufacturing arsenal.

(3) Command of a Ordnance Depot, detail at a large industrial plant, or duty in an Ordnance District (including war plans affecting munitions).

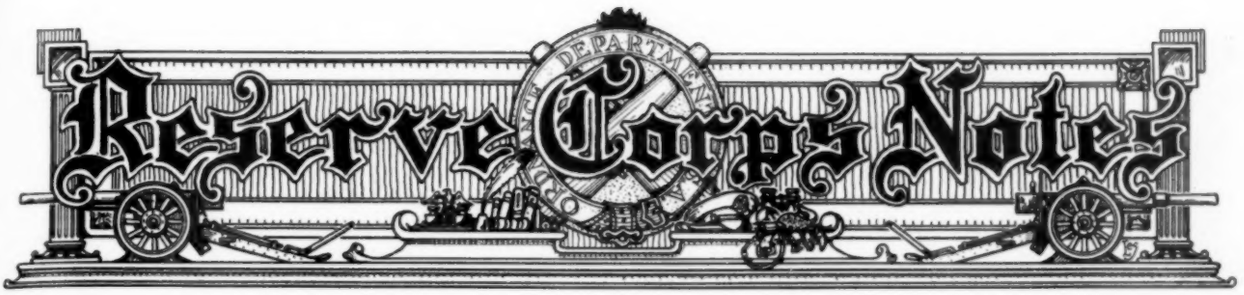
(4) Duty as Corps Area, Division, Department, Camp, or Post Ordnance Officer, or Ordnance duty in direct contact with the Line.

Obviously a superior officer of the Ordnance Department may qualify as a superior Ordnance Officer in a few years' service, whereas an average officer may require twice the time in the Ordnance Department under most favorable assignments to qualify as an average Ordnance Officer. Obviously also a number of officers in the corps may have had occasion to handle but a few assignments and even though they have performed these duties in a superior manner their goal is yet some distance off. Thrice obvious is the fact that the officers who have survived the continuous reduction and elimination of commissioned personnel since the World War and who have accomplished work equivalent to that given in the preceding paragraph are full-fledged Ordnance Officers with a standard efficiency as high as that in any Army in the World.

But this does not mean that there is no room for improvement. Every experienced Ordnance Officer, at least every one known to the writer, will admit that he is striving for further knowledge that will materially benefit him.

With changes in station necessitated by law at a minimum of 40 per cent of Ordnance commissioned personnel annually the opportunity is ever present to broaden one's professional knowledge even though it be at the expense of developing relatively few specialists. Combined with this necessity for change of station (20 per cent service with troops) is the very liberal policy of the Ordnance Office to comply with the officer's choice of assignment as far as practicable. There is, therefore, a bright outlook for all junior officers of the Corps to qualify as Ordnance Officers.

(Continued on page 238)



The Chief of Ordnance has asked for the allotment of sufficient funds to call a number of reserve officers to active duty in the office of the Chief of Ordnance, at all arsenals and at all Ordnance District Offices for the 1923 summer training. The total number of reserve officers actually called to duty will depend upon the funds appropriated by Congress for pay and mileage; the number of Ordnance Reserve Officers to whom training can be given will depend upon the apportionment of these funds to the several territorial departments and branches of the Army.

The following status of Ordnance Companies in the National Guard is given:

	Auth.	Fed. Recognized.
Ordnance Companies (Maintenance) Inf. Div	18	4
Ordnance Companies (Heavy Maintenance) Special Corps Troops	3	0
Ordnance Companies (Maintenance) Cavalry Div	2	0
Ordnance Companies (Maintenance) Army	2	0

The following have recently accepted commissions in the Ordnance Officers' Reserve Corps:

Col. Charles L. Harrison, Lieut. Col. Arthur E. Barter, Lieut. Col. Edward J. Parish, Lieut. Col. Milo D. Snyder, Lieut. Col. Robert L. Streeter, Major Ross R. Harrison, Major James T. Moodey, Major David M. Salter, Major Charles C. Stanchfield, Capt. Edwin F. Moody, Capt. James E. Moorhead, Capt. William E. Robinson, Capt. James Tittle, First Lieut. Claude L. Allen, First Lieut. Alfred G. Ashcroft, First Lieut. George L. Hunt, First Lieut. Charles J. O'Neill, First Lieut. Prosper Russo, First Lieut. Henry E. Suavet, First Lieut. Paul Tanner, First Lieut. Rockwell C. Tenney, Second Lieut. Charles M. Conaway, Second Lieut. Joseph W. Gable, Second Lieut. George G. Leavitt, Second Lieut. Paul S. Liscord, Second Lieut. Campbell R. McCullough, Second Lieut. Robert A. Muller, Second Lieut. Lesley C. Robertson, Second Lieut. Fred M. Thrun.

The Army Correspondence Courses for reserve officers includes the Basic Military Ordnance Course "A," which should be taken by all Ordnance Reserve Officers. This is a refresher course for officers with previous military experience. It is planned that additional courses will be available during the next fiscal year.

The Ordnance Officer, Second Corps Area, at the request of a number of Reserve Officers living in the vicinity of New York, has made arrangements through the Ordnance Office, Washington, to hold a three (3) days' course of instruction for Reserve Officers of the Ordnance Department at Raritan Arsenal, on February 8, 9, and 10, 1923. The course of instruction is intended to briefly cover the activities and equipment of the Ordnance Maintenance Companies. The officers attending are to do so at their own expense and not on an active duty status. At the date of going to press the number of officers that have signified a willingness to attend is about fifteen (15).

The following instruction from The Adjutant General of the Army for Field training and training of the Reserves for the summer of 1923 is published:

"*Reserves.*—In so far as practicable the following policy will be followed in organizing and administering camps for training the Organized Reserves:

The object of the camps is the practical field training of officers and units in operations of the combined arms, and the further development of unit organization and esprit. Officers will be assembled by division, the command and staff of each unit within the division being at least partially represented. Attached officers may be assigned to units for the period of the camps to fill vacancies caused by non-attendance of assigned officers in corresponding grades and branches. Non-divisional groups will be assembled by tactical units thereof, the command and staff of subordinate units being at least partially represented.

Reserve officers assigned to the Coast Artillery Corps who may be selected for training, will be assembled at a suitable coast defense command. Reserve Officers of the Air Service will be assembled at such air fields within the corps area, as are suitable for the purpose, preference being given to fields which favor combined training with other branches of the service. A commander of a corps area where facilities do not exist for training reserve officers of the Coast Artillery Corps and Air Service, will arrange with the commander of another corps area for training officers of these services whom he may select.

Training will be conducted by conferences, by tactical exercises and by demonstrations preferably illustrating features of the tactical exercises, in accordance with a War Department program to be issued in further detail early in the calendar year 1923. This program will be in the form of an annual fiscal year project for the training of reserve officers to include not only 15 days' training in summer camps indicated above, but also 15 days' training for selected officers at corps area or unit headquarters, and with organizations of the Regular Army, and courses of instruction for limited numbers of reserve officers at the various service schools."

HOTEL ASTOR

ARMY *and* NAVY HEADQUARTERS

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F. A. MUSCHENHEIM

Artillery Division Notes

Demonstration of 2½-Ton Roadless Mack Truck.—The International Motor Company, of New York, in cooperation with the Roadless Patents Holding Company, of Washington, D. C., has recently developed an adapter type truck of 2½-tons capacity, a very interesting demonstration of which was given by these two companies in Rock Creek Park, Washington, D. C., on Friday, December 22, 1922.

While this particular vehicle demonstrated was developed for commercial purposes primarily, the general principles of construction used are applicable to the various types of military vehicles, and the Ordnance Department was particularly interested in the demonstration given as indicating what the probable performance will be of the Army tractor, Model 1922, which incorporates this same type of chain suspension and flexible track. In addition to its use on the Army tractor, it is further contemplated that the suspension and track of the new Medium tank, Model 1924, will also be constructed along the same general lines.

The vehicle demonstrated in Rock Creek Park consists of a standard model AB 2½-ton Mack truck, from which the rear springs and wheels have been removed and the chain suspension with a flexible track applied. The rear axle is rigidly connected to the truck chassis and is so located that the drive sprockets which replace the rear wheels are normally not in contact with the ground. The track frames are mounted on an unsprung axle near their center, and at the front of the track frame there is a connection to the truck chassis through a double acting coil spring. The flexible track is of the same type as that described in the Artillery Notes of the "Army Ordnance" for November-December 1922, page 173.

The total weight of this truck is 10,600 pounds, and on hard roads where only the rubber pads of the track shoes are in contact with the ground, the unit ground pressure is approximately 13½ pounds per square inch, which figure is reduced to 9½ pounds per square inch when on soft ground the steel shoe comes in supporting contact with the ground.

The power transmission system is practically the same as in the standard 2½-ton Mack truck, the only exception being the final fixed reduction, which in the case of the adapter type vehicle carries a greater reduction. With a governed engine speed of 1,275 r. p. m., the adapter track speed is 10.83 miles per hour in fourth speed, and 2.23 miles per hour in low gear, with a speed in reverse of 1.45 miles per hour.

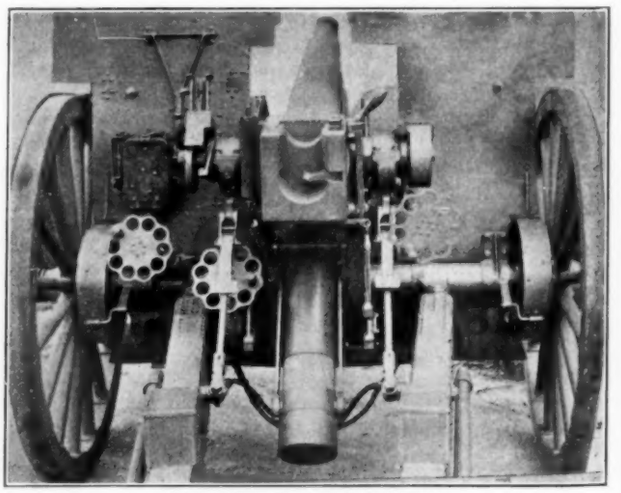
Steering is accomplished by turning the front wheels in the usual manner as with the ordinary four-wheeled vehicle, and due to the universal action made possible with the track shoe construction used, the tracks are laid down in a curve of radius equal to the minimum turning radius as determined by the front wheels. Where the imprint of the track is shown on a road surface covered with flour, the rubber pads on the shoes are very clearly outlined, thereby proving that there is no side slipping of either track in effecting the turn.

In the demonstration given in Rock Creek Park, the vehicle was first maneuvered on a smooth road surface to demonstrate its ability to turn on a short radius without skidding on the tracks. The vehicle was also run over a series of obstructions, such as pieces of 2x4 lumber, showing clearly the flexibility of the chain suspension, which showed contact of the track on the road surface even when passing over such obstructions, thereby insuring an excellent traction with relatively low ground pressure.

The demonstration in the Park consisted of maneuvering over muddy roads and uneven ground in an open field, and in testing the vehicle on all kinds of ground surface. During the maneuvering a ditch of approximately 6 feet in depth and 10 feet in width was crossed without difficulty, and in attempting to recross in the opposite direction, trouble was encountered on account of the slippery condition of the ground surface. The vehicle pulled out under its own power, however, when the vehicle was maneuvered so that the tracks were able to grip properly on the ground. Throughout the demonstration the truck carried its normal load of 2½ tons.

Traveling Lock.—Divisional Artillery when limbered and being hauled over rough terrain is subjected to many stresses in the structural parts that cannot be computed. To facilitate manufacture it is necessary to provide clearance between fitting parts to permit of easy assembly. There is also some deflection in the axle and other parts due to the weight of the gun and recoil mechanism. In practice it has been found that these clearances, tolerances and deflections affect the whole carriage, causing noise, increasing the wear on loose parts and tending to cause rupture in other parts that have to carry added load due to its unequal distribution.

Traveling locks of various types have been tried to take up the lost motion between the gun and trails on the road. These usually take the form of a bar pivotally attached to one trail and capable of being swung across to the other where it is securely fastened. Near the center of this bar a seat is provided to attach the rear end of the gun or cradle. This construction generally resists both elevation and traverse of the gun. Any deflection in the bar or its attachments may interfere with its proper functioning.



45 mm. Gun Carriage, Model 1923E

They have to be fitted to each carriage and are not interchangeable even among similar gun carriages in the same battery.

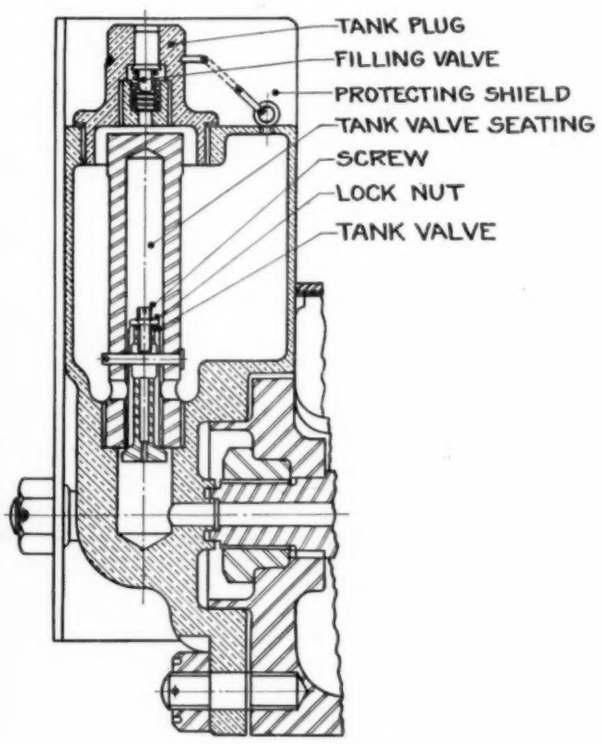
The traveling locks for the 75-millimeter Gun Carriage, M. 1923E, are attached to lugs on the top carriage into which a short straight pin is driven. Two traveling locks

are provided, one on either side, and are shown in the illustration of the carriage. One end is securely fastened to the trail in such a manner that it can be readily adjusted for length. It is mounted in a bracket on the trail so that it can swing freely. It is adjustable for length by threading the end and screwing it into the socket and is locked with a split pin. The upper end is shaped like an open hook, and engages the pin in the lug of the top carriage. An eccentric pin, operated by a handle, serves to release or engage the assembled tie rod. When in use it is practically an adjustable tie rod connecting the top carriage and trail. All parts are simple to manufacture. The adjustable feature makes it unnecessary to have the parts line up accurately when assembling. The eccentric and lever puts considerable tension in the rod, and takes up all the lost motion in the bearings in the axle and in the axle arms.

A cradle lock is also provided consisting of an "A" frame lock between the axle in front and the lower side of the cradle.

Gravity Tanks on 75-millimeter Gun Carriage, Model 1917 (British).—Rock Island Arsenal is modifying 75-millimeter Gun Carriages, Model 1917 (British) by the addition of gravity tanks. The purpose of these tanks is to automatically replace in the recoil cylinder any oil that may be lost during service. The loss of oil is generally only that lost through the stuffing box packing.

The gravity tank is a bronze casting with a capacity of about 3 pints, secured to the front end of the cradle and



GRAVITY TANK ASSEMBLY

protected by an armor plate shield. It is conected to the front end of the piston rod, and a hole through the piston rod permits the oil to pass through it to the buffer chamber in the rear of the piston rod. A filling valve is provided in the top of the tank, designed to admit atmospheric pressure, allowing oil to go into the mechanism or to close when there is pressure in the tank. A valve is located in the bottom of the tank to control the flow of oil from the tank during recoil and into the tank during counter recoil. There is a throttling effect during counter recoil that assists the counter recoil buffer in controlling the return of the gun into battery.

In the final assembly and adjustment of the tank valve, it is necessary to adjust each valve to its carriage. This adjustment consists in enlarging the 0.33-inch opening at the bottom of the valve until the gun counter recoils properly. It was found that shop test adjustment does not give the same results as during firing. When retracting the gun in the shop the comparatively slow movement of the piece to the rear allows a larger amount of oil to pass from the gravity tank to the recoil system, so that when the gun is tripped to counter recoil, it stops out of battery and then moves slowly into battery. The speed of going into battery depends directly on the size of the opening at the lower end of the tank valve. The final movement of the gun during the last few inches in counter recoil is the only guide as to the proper adjustment of the tank valve, and this adjustment probably varies under different conditions of temperature and with different oil viscosities.

In order to provide an adjustment which can be easily made, it is proposed to provide a lock nut and screw in the upper end of the tank valve to give an adjustment of the lift, which controls the amount of oil entering the recoil system from the gravity tank during recoil of the gun. If upon firing it is found that the gun returns to battery too violently, the adjusting screw should be screwed out of the valve and the lock nut secured. This allows greater play to the valve and more oil may enter the system during recoil. If the gun stops some distance out of battery during counter recoil, the adjusting screw should be screwed in, thus decreasing the play of the valve, and allowing less oil to enter the system, and permitting the gun to go entirely into battery. The adjustment of the valve may be made by means of this screw and lock nut to allow a vertical play of the valve from zero to 0.25 inch, and to increase or decrease the amount of oil entering the system between the limits made by these settings. An opening of 0.046 inch in the tank valve with this vertical play gave satisfactory results.

The tank valve is accessible for adjustment after removing the tank plug, which contains the tank filling valve. To adjust the tank valve, the valve seating tank in which it is located must be removed from the gravity tank through the tank plug hole.

Demonstration of Land and Water Type of Motor Gun Carriage by the Front Drive Motor Co.—An interesting type of motor carriage for the 75 millimeter gun was demonstrated in New York recently as part of the program at the annual meeting of the A. S. M. E. The carriage shown was designed by Mr. Walter Christie, the President of the Front Drive Motor Company. This company has also built a number of experimental war service vehicles for the United States, incorporating the combined wheel and track feature. This latest vehicle made by the company on its own account, not only has the convertible track feature, but in addition, has been constructed to float and operate in water.

This vehicle, shown in the accompanying illustrations, can be operated on land or in the water. During the demonstration in New York, the carriage crossed the Hudson River under its own power, climbed steep hills on the New Jersey side of the river on its tracks, and maneuvered over good roads on its wheels.

This carriage is of the combined wheel- and track-laying type which is adapted to run on solid rubber-tired wheels,

or on tracks which pass over the wheels and are driven by the wheels at the rear.

The body is built-up of light plates, and is made watertight for operation in water. Buoyancy is obtained by floats of balsa wood encased in sheet iron. These floats extend along the side of the body over the wheels. The transverse section of the body is shaped like the letter T, the vertical portion being between the wheels, while the top portion overhangs the wheels.

For maneuvering in water, two propellers are provided at the rear of the machine. These are connected to and driven by the transmission. The propellers revolve only when the carriage is in the water, and are engaged or disengaged by hand before entering water and when leaving.

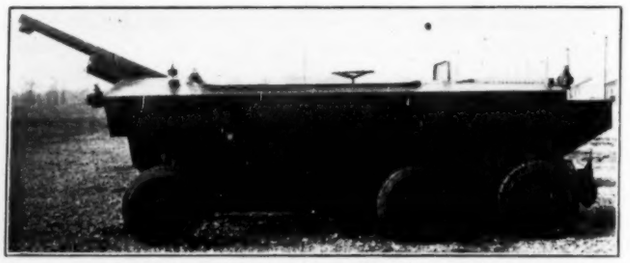
The location of the gun is reversed from the mounting used on similar experimental carriages made by the same manufacturer for the United States. The muzzle points in the direction of forward motion and recoils back into the center of the vehicle body which forms a recoil pit.

The gun is mounted on a sliding base which is moved forward and locked in place for firing. In the firing position, a center post, cone shaped, with the small end down, extends below the center of the gun mount, and is locked at the small end to the end plate of the vehicle body. This post takes the overturning effort and prevents the supporting plate from bending. In the traveling position, the center post is released at the bottom and the entire mount moved back and is locked in place. In the traveling position, the gun is also supported in and locked to the end plate of the vehicle.

There are three wheels on each side, a steering wheel, a driving wheel, and a center wheel between the steering wheel and the driving wheel. The center wheel is not spaced midway between the steering wheel and the driving wheel, but is located just ahead of the driving wheel and is driven from the drive wheel by means of a chain and sprockets on the outside of the wheels.

The steering wheels are sprung individually in the usual manner, using coil springs housed in tubes above the wheels and in the body; the center or auxiliary wheels are also individually sprung using coil springs, while the drive wheels are not sprung. These wheels are driven direct from the transmission by internal spur and pinion. In operation on wheels, the center wheels become the drive wheels through the drive chains from the rear wheels, the rear wheels being raised clear of the ground by lowering the auxiliary wheels.

When the vehicle is running on wheels, the tracks are separated into several short sections and carried inside of



75 mm. Gun Carriage, Christie Combined Wheel, Track-laying and Self-Propelled Floating Type

the vehicle. With this arrangement, the short sections of track must be thrown out of the vehicle before the gun can be manned.

As a track-laying vehicle, with the rear wheel acting as drive wheel for the track and with the rear wheel on the ground, the rear of the vehicle, the heavy part of the vehicle, is unsprung, excepting for the spring effect on the auxiliary wheels. The track drive action is exactly the same as in all previous types of the Christie design.

When operating as a wheeled vehicle, steering is by the steering wheels assisted by declutching one of the driving wheels. When the tracks are used, the steering wheels are

Christie Land-and-Water Type of Motor Gun Carriage Maneuvering in Water

locked in position and steering is accomplished by declutching power to one track or the other.

The principal dimensions and characteristics of the carriage are given in the following table:

Weight with gun and tracks	14,000 pounds
Maximum height overall	16 ft. 5 in.
Maximum overall width (over wheels and floats)	79 inches
Height of center line of gun	60½ inches
Length of track in contact with ground	144 inches
Width of track shoes	10 inches
Height of track drive lug	5 inches
Pitch of track shoe	10 inches
Diameter of drive wheels over tires	31 inches
Diameter of steering wheels over tires	31 inches
Diameter of center wheels	31 inches
Center wheel drive	By chain.
Spring suspension, drive wheel	No.
Spring suspension, center	Yes.
Spring suspension, steering	Yes.
Type of body	Hull, watertight.
Engine, H. P.	
Type	T-Head
Number of cylinders	4
Bore and stroke	5½ by 7
Transmission	Gear
Number of speeds, forward	3
Number of speeds, reverse	3
Gear ratio, forward—high	1 to 7½
Gear ratio, forward—low	1:49
Final drive	Internal spur gear and pinion.
Capacity of fuel tank	53 gallons.
Number of propellers	2
Diameter of propellers	26 inches.

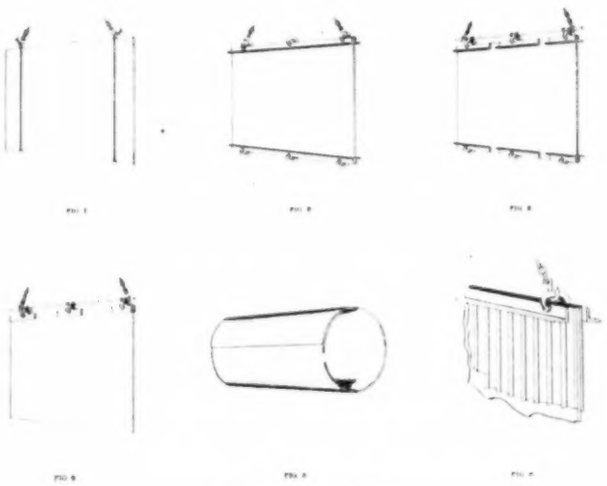
Rock Island Arsenal Notes

Quenching Duralumin.—The manufacture of two of the 600 and 900 pound Tractor Power Carts and two of the 800 and 1,600 pound Reconnaissance Tractors called for duralumin sheets of which the floating bodies were made. The majority of the sheets were 3/32-inch thick and in various sizes from about 3 feet by 5 feet to 4 feet by 11 feet. The physical characteristics of the metal desired were such that heat treatment of the duralumin was necessary.

Very little data on the proper methods of fabrication of this aluminum alloy were available. The manufacturers of the alloy advised that the metal should be heat tested after the forming operations to give the desired physical properties and to quench either in cold or hot water. Only with the metal in its softest condition, that is, annealed, was it considered possible to perform the bending and drawing operations required. Further, the data that were available were largely laboratory data secured with small specimens of duralumin and in no way represented experience given in actual fabrication of the alloy in such large sheets or under the difficult conditions called for in the various designs of tractor power carts and reconnaissance trac-

tors. Inquiry disclosed the fact that no other manufacturer in the country had used duralumin in the quantity or under the conditions which Rock Island Arsenal was about to.

The heat treatment of the large duralumin sheets necessitated the installation of special heat treating equipment.



Quenching Duralumin

A nitre bath was constructed, the inside dimensions of the pot being 11 feet 4 inches in length, 2 feet 6 inches wide, and 4 feet deep. A quenching tank of similar size with provision for heating the water was also constructed. Preliminary investigation was initiated to determine proper methods of forming and drawing the metal.

Since some of the bends and drawing operations to which certain of the sheets were to be subjected were considered severe, the manufacturers' advice to cut and form the duralumin first and then heat treat, was followed. Material was first suspended by loops of wire in the nitre bath and held at 935 degrees Fahrenheit for thirty minutes, followed by quenching in hot water. The results were far from encouraging. The rear end of the tractor power cart, the upper edge of which is bent over a reinforcing rod, came out of the quench comparatively straight at the upped edge, but the remainder of the sheet was buckled and warped to such an extent that hand straightening was required. Observation of the lower edge of the sheet which hung in the wire loops showed that the metal had softened sufficiently while in the nitre bath to allow the wire to cut into the lower edge of the sheet about one-eighth of an inch. It was at once decided that the method of suspension allowed the weight of the softened duralumin to sag between supports with the resultant buckling. (Fig. 1.)

At this point it was suggested that the only way to handle a thin sheet of duralumin of large dimension and practically flat was to resort to a quenching press procedure. The idea was considered entirely too bold, however, when the size of the sheets was considered. It was thought that the construction of a suitable quenching press would be so costly as to make the operation entirely impracticable and the idea, therefore, was given no further consideration at the time.

Supplementary experiments in bending and drawing the metal supplied data by this time which indicated that most of the forming operations, which the bodies of these vehicles required, could be done on 3/32-inch thick sheets after heat treatment, and before the material had acquired its maximum physical characteristics on aging. It was decided, therefore, to cut the sheet, then heat treat and as soon as possible thereafter do the necessary forming operations. Certain of these operations required that the material be heated locally with a torch in order to prevent breaking or cracking.

The next group of sheets was prepared for suspension in the nitre bath for heat treatment by placing a light steel angle on each side along the top edge and clamping the angles to the duralumin sheets by means of small clamps. Along the bottom edge of the sheets similar angles and clamps were placed. It was thought that the angles along the top and bottom edges would hold duralumin sheets straight and prevent the excessive buckling at first experienced and, in addition, the weight of the angles and clamps along the bottom edge would cause the duralumin sheets to enter the quenching medium more rapidly. It was observed that this group of sheets when removed from the nitre bath was as straight as before heat treatment, but after quenching the sheets buckled and distorted almost as much as previously experienced. It was noted also that the metal underneath the angles remained comparatively straight, but that the portion of the sheet between the upper and lower stiffening angles apparently expanded and buckled excessively, requiring hand straightening in order that the material might be used. (Fig. 2.)

In order to allow the duralumin sheet to expand along the edges stiffened by the steel angles the next few sheets were suspended by the angles and clamps as above, but the angles instead of being as long as the sheets, were made in lengths of a foot or two with a space of about two inches between each set of angles. After quenching, the sheets were slightly straighter than those secured previously, but the buckling and distortion was still such that costly hand straightening had to be resorted to before the material could be formed. (Fig. 3.)

The sheets were next suspended by attaching several clamps to the upper edges, securing these clamps by means of wire to a rod and suspending the entire sheet and its fastenings from this rod. This gave sheets about as straight as any that had been secured. (Fig. 4.)

It was then decided to observe the results of light quenching frames clamped to each side of the duralumin sheets. These were constructed of light flange steel, corrugated, and were held together by placing a light steel angle along each side of the upper and lower edges and securing the whole together with clamps. The corrugations not only gave the quenching frame considerable stiffness, but allowed the entrance and exit of the molten nitrate and the quenching medium. The duralumin sheets inclosed in their quenching frames were withdrawn from the nitre bath as straight as they entered. Upon quenching, however, the forces, due to the uneven distortion of the quenched duralumin sheet, were of such magnitude that the quenching frame itself was sprung open in several places. The idea of the light quenching frame was abandoned, the resultant quenched sheets being no straighter than secured by other methods of suspension. (Fig. 6.)

The size of the sheets were such that they could not be laid flat in a cradle emersed in the nitre bath for heat treatment. This method was suggested by the manufacturers. Observations showed, however, that the excessive buckling encountered was not due to the sagging of the metal due to its own weight while in the nitre bath, but was caused instead when the thin duralumin sheet was quenched in water. The construction of a nitre pot, therefore, of such dimensions that the sheets could be laid flat would be a waste of time and money.

Observation of smaller articles of duralumin sheet formed before heat treatment showed that very little distortion resulted upon quenching due, undoubtedly, to the structural stiffness imparted to the article after forming. It was sug-

gested, therefore, that the large sheets be rolled into cylinders of large diameter, then suspended in the nitre pot, quenched and then unrolled. This was done and only minor distortion was experienced upon quenching. When the sheets were unrolled a few buckles reappeared, although this method gave the best results so far. It was felt, however, with the extra labor involved in rolling and unrolling the sheets coupled with the fact that a certain amount of hand straightening was still required, prompted the continuation of experiments to determine a method of heat treating and quenching thin flat duralumin sheets cheaply and with the minimum of distortion. (Fig. 5.)

Most of the material required in the manufacture of the tractor power carts and reconnaissance tractors had been heat treated, hand straightened and then formed, by this time. Supplementary experiments gave additional data concerning heat treatment of this material. It was found that the duralumin, when heated to 935 degrees Fahrenheit, and allowed to cool in the air, showed an increase in tensile strength and hardness upon aging. The idea of following quenching press procedure was, therefore, given further attention. It was felt that should a sheet of duralumin be heated to the proper temperature and then placed between cast iron plates in a press, the duralumin sheet would quench satisfactorily and with sufficient rapidity to develop the maximum physical characteristics. This method would make the use of a nitre bath impossible, however, since the comparatively heavy film of nitrate which adheres to the duralumin sheet upon its removal from the bath would give an irregular and bumpy surface between the sheet of duralumin and the cast iron quenching plates. To determine the value of this method, a sheet of duralumin, which was first "upset" in several places, was heated in a muffle furnace and held at about 935 degrees Fahrenheit. It was then removed to a hydraulic press of small capacity and compressed between the upper and lower cast iron plates of the press. After a minute the sheet was removed for observation. The results were decidedly encouraging since the sheet upon removal from the press was just as straight as could be desired. Even those portions which had previously been "upset" were now entirely flat. Very little pressure was used in the press.

This last experiment was especially important in that it indicated means of cutting the cost of heat treatment considerably. In the first place the large and costly nitre pot could be replaced by a less expensive muffled furnace. The use of a light portable electric plate or oven is entirely practicable and merits trial, and the fact that a temperature of only 935 degrees Fahrenheit is necessary for heat treatment of duralumin must not be lost sight of, and the construction of a furnace to maintain heat of 1,600 degrees Fahrenheit need not be attempted. Further, the flat sheets secured by quenching between plates in a press does away with the costly straightening.

In conclusion it may be said that no unusual trouble from excessive distortion due to quenching will be experienced with small formed or stamped articles made of duralumin sheet and heat treated in a nitre bath. The shape of the article will usually lend sufficient structural stiffness to prevent undesirable buckling during heat treatment and the smaller the article the less objectionable will be the resultant distortion. The effect of the shape of the article is well brought out in the experiment with sheets rolled in cylinders. If, however, it is contemplated to utilize the duralumin sheet in such large pieces and in such shapes as called for in building the tractor power carts and reconnaissance tractors, the use of a muffle or electric furnace, followed by a quench between cast iron plates in a press, offers an opportunity to dispense with the costly nitre pot and its high cost of maintenance, and secure with equipment already on hand heat treated and flat duralumin sheets with a minimum expenditure of time and money.

Reconditioning Recuperators for Gun Carriage, Model 1897 (French).—Rock Island Arsenal has just completed, nearly simultaneously, repair work on the disassembly and preparation for storage of 411 recuperators received back from service in France and which had originally been manufactured by and purchased from the French government, and the repair of a lot of recuperators for Gun Carriage, Model 1897 (French), which were manufactured in this country and which were in use by troops in this country from the middle part of 1919 to the Fall of 1922. The observations made during this work are of interest as indicating what may be expected in the maintenance of this class of matériel.

The 411 recuperators returned from France were entirely disassembled. In general, it was found that about one-half of one per cent of all Belleville springs and one-tenth of one per cent of all coil springs had to be replaced, all of the copper rings and silver rings had to be reworked, one hundred per cent of all rubber and leather washers had to be replaced. In nearly all cases it was found that the leather and rubber washers were functioning satisfactorily, but when disassembled the leather washers were discovered to be very hard and brittle and unserviceable for reassembly. In many cases the leather washers were found to be severely scorched and burned, showing evidence of a high rate of fire to which they had been subjected. The corresponding gun books showed rates of fire of from 400 to 500 rounds per day during the early days of November, 1918. Recuperators were found which were filled with oil of all varieties, one being filled with linseed oil. These recuperators apparently had been still giving service. In many cases recuperators were found to be dented, evidently from being struck with projectiles. In cases where these dents were on the top surface and guide rails this damage was repaired by the insertion of small pieces. When the dent was in the cylinder walls it could, in some cases, be removed by lapping, but in several it was necessary to reject the recuperator. In one case it was found that the dent in the cylinder wall had worn a corresponding groove in the piston head, showing that the gun had continued to function even after being struck. In a great many cases where the Belleville springs were found broken, the gun had apparently continued giving service, but in some of these cases the broken Belleville springs had scored the piston rod so severely as to make its replacement necessary. In several recuperators it was found that there was no grease in the floating piston and even in these cases the air pressure had not been lost. In only four cases were recuperators found with the air pressure entirely lost. Due to lack of necessary funds, the 411 recuperators were not reassembled, but were thoroughly greased and placed in storage in a disassembled condition awaiting a time when the funds might be available.. From cost records on a provious lot of 2,000 recuperators returned from France and similarly reconditioned and reassembled, the cost of this work was found to be $325 per recuperator.

When the 30 recuperators which were in use in this country was received in the shop, work was started along similar lines, to recondition; that is, complete disassembly, replacement of worn out parts and reassembly. Two recuperators were actually torn down, but the condition of these was found to be so good that it was decided not to go through the very expensive operation of complete disassembly, except in cases where absolutely essential. Instead, the recuperators were first subjected to a number of test pulls to obtain the time of counter recoil. If this

was satisfactory, the recuperators were next placed on a machine where the friction on the packing in the oil cylinder and in the floating piston was obtained. Only in cases of unsatisfactory friction on the floating piston was it considered necessary to completely disassemble the recuperator. From the actual check on these thirty recuperators only four were found that needed complete disassembly due to this cause. In other cases where the friction was poor in the oil piston, this piston was repacked. In all cases it was found necessary to add a small amount of air pressure. However, in all thirty cylinders the air was found to be only slightly below the required pressure. After adding this air, the recuperators were proof-fired and if they functioned satisfactorily, no further work on the reconditioning of them was done. In some cases proof-firing, however, developed difficulties which had not previously shown up, such as too long a recoil, air mixed in with the oil, foreign substances in the regulator, leaky packings, broken Belleville springs. Due to the defects developed in the proof-firing, it was found necessary to disassemble completely two more of the recuperators, making a total of eight recuperators out of the thirty which it was found necessary to completely disassemble. In these thirty recuperators, seven piston rods were found which were so badly scored as to necessitate replacement. Three regulators were found which had to be replaced due to leaking valves and four Belleville springs were found broken. The method of reconditioning these thirty recuperators was found to be much more inexpensive than the complete disassembly formerly used, the cost per recuperator amounting to $70 and this method is thought to be satisfactory for matériel which has not been exposed to the rigorous use of war conditions.

Watervliet Arsenal Notes

Machining Rotating Racks on Breech Blocks.—The construction of the rotating rack on the breech block for 12-inch Mortars, Models 1908 and 1912, and 14-inch Guns, Models

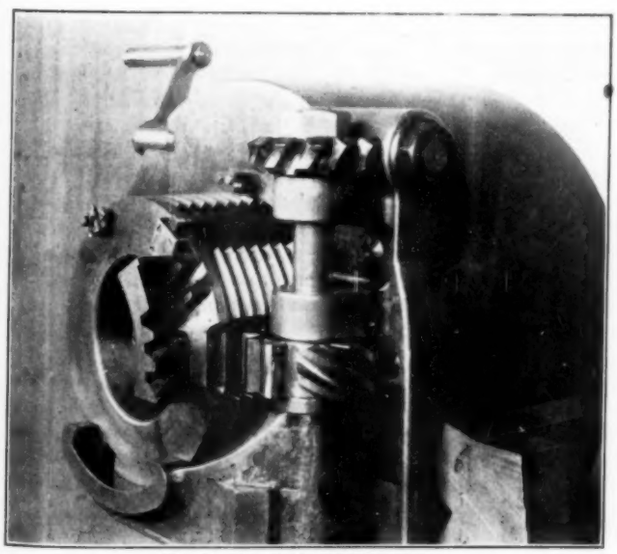
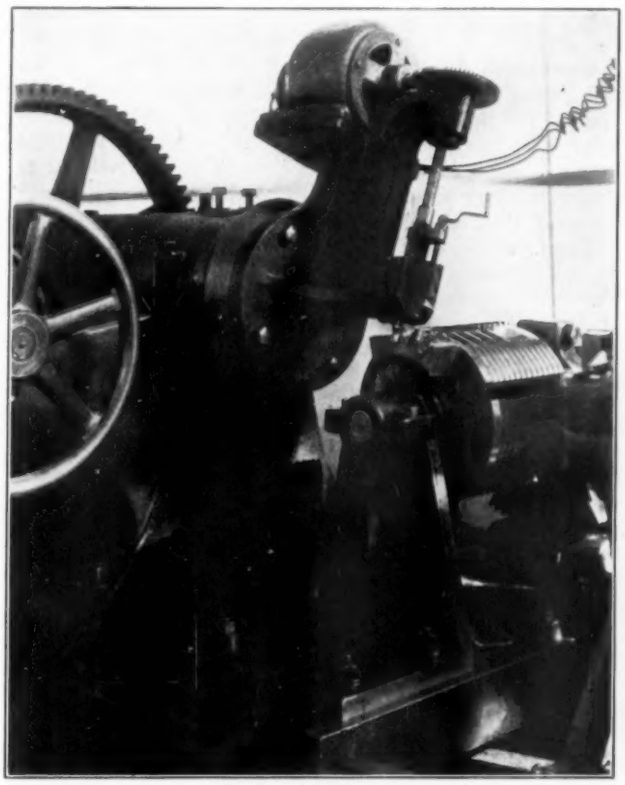


Fig. 1. Machining Rotating Racks

1907, 1909, and 1910, is such that the machining thereof cannot be accomplished with the machine equipment ordinarily found in the modern shop. Figure No. 1 shows a shop dummy of the 12-inch Mortar, Model 1908, with the breech block partly withdrawn, so as to show the rotating rack on the rear and a portion of the translating rack on the side. The compound gear is shown engaged in the translating rack and, as will be noted, is a combination spur and spiral gear, the spur teeth being used to translate the



Machining Rotating Lock

block and the spiral teeth to rotate it, both motions being imparted by the same gear and in one turn.

The design of the gearing is such that there is scarcely any lost motion in the change from rotation to translation and vice versa, the opening or closing of the block being done by one continuous turning of the crank shown at the top left side of the dummy. The location of the teeth of the two racks in relation to each other and to the thread on the exterior of the block must be accurately established in order that the change of motion from translation to rotation may be accomplished with ease and at the proper moment. It will also be noted that the exterior of the block is threaded, the pitch or lead of which is 1 inch. The rotating rack must have a corresponding pitch or lead in order that the point of contact between the rack and compound gear will at all times be in the center line of the rack.

In view of the above conditions, three distinct and simultaneous motions are required in the machining of the teeth of the rotating rack—namely, rotation of the block upon its axis, longitudinal movement or progression of the block during rotation, corresponding to the pitch of the thread and the radial movement of the milling attachment to correspond with the radius of the compound gear.

In order to accomplish the above movements, special equipment, as shown by Figure 2, is employed at the Watervliet Arsenal. The equipment consists of an old type horizontal jacket or hoop boring machine which was utilized by removing the boring bar and outboard bearing and assembling to the main spindle a special arm or bracket which

carries a movable spindle for the insertion of the milling cutter, vertical adjustment being obtained by means of the small crank and screw which are connected to the spindle. Power is supplied to the milling cutter by means of the small motor mounted on the spindle bracket. The radial movement of the milling attachment is accomplished by means of the hand wheel at the left of the figure, which is keyed to the main shaft carrying the belt cone and which has a pinion at the end thereof connecting through intermediate gears with the large gear seen at the rear of the main spindle. This gear has been counterweighted to compensate for the overhanging weight of the milling attachment. The breech block is mounted on an arbor in a special fixture, the height of which must be in proper relation to the swinging milling bracket in order to obtain the proper radius of the rotating rack. The breech block is kept from rotating on the arbor by a nut bearing against a large washer fitting in the tapered cavity of the breech block. This arbor has an Acme thread cut on the rear end, the lead of which is the same as that of the thread on the block. A stud fitting into this thread is located in the rear housing which carries the arbor and causes a longitudinal movement of the block corresponding to the pitch of the thread when the block is rotated. There is also carried on the arbor a gear segment which meshes with the worm located on the fixture below the breech block. This worm is connected to the gearing at the rear of the machine by means of two shafts and universal joints the necessary change gearing required to obtain the proper pitch of the rotating rack being carried on a quadrant and meshing through intermediate gears with the gear on the main spindle.

From the above, it will be noted that the various movements of the block required during the machining operations are obtained by connecting gearing so that the simple movement of the hand wheel will cause the block to move along the path of the center line of the rack while the milling cutter is being rotated about a center corresponding to the center of the compound gear.

After assembling the breech block in the fixture, the guide stud or pin is inserted in the Acme thread of the arbor previously described and held securely in place, but the necessary gearing required to rotate the block is not connected. The translating rack on the block is machined prior to this operation, but the lug in which the rotating rack is cut has only been turned and finished on rear face and ends, the rear face being machined parallel also with the threads of the block.

A locating templet is applied to the rear face of the lug and lays out the center line of the rotating rack at each end of lug, stop surfaces for the compound gear at each end of the rack, and a line indicating the depth to which the lug must be machined prior to milling the teeth—i. e., the line on the rear face of lug at the top of the spiral teeth.

The machining of the lug preparatory to milling of teeth, as well as the clearance space between the translating and rotating racks, is done by means of an ordinary end mill inserted in the swinging milling bracket, the block having been set longitudinally to coincide with the vertical center line of the swinging bracket and lug having been laid out as noted above. Due to the influence of the guide pin in the threaded arbor, the block is moved longitudinally while being rotated an amount commensurate with the pitch of the thread and, consequently, the center line of the top radius of the rack is parallel with the thread.

After milling the radius and clearance as described above, the center line of rack and the center line of each tooth space is carefully laid out, the center lines of the rotating and translating racks intersecting in the center of the first tooth space. When the rack has been properly laid out a fine setting point is placed in the spindle of the milling attachment and the gearing between the breech block arbor and the main spindle connected. The swinging bracket is then rotated by means of the hand wheel and breech block adjusted so that the setting point in the milling spindle passes through and coincides with the center line of the space to be cut. Longitudinal adjustment of the fixture base is obtained by means of an adjusting screw located in the bed of the machine. Longitudinal adjustment of the block is obtained by necessary movement of the rear bracket, the block arbor sliding freely in the bearing of the front bracket.

Great care must be observed in the setting operation that all back-lash in the gearing be held in the same direction as applies during the milling operation. After the setting operation is completed, the space is machined out with a form mill and fitted to a locating templet. The remaining spaces are cut in a similar manner, the spacing being checked by form templates.

Straightening 14-inch Gun Model of 1907 M1.—Fourteen-inch Gun Model of 1907 M1, number 1 was recently returned to Watervliet Arsenal for relining. This gun, which is 34 calibers in length, as originally built, was not provided with a liner, making it necessary to machine a seat in the tube proper for the assembly of the liner.

On setting up the gun in the lathe for boring the liner seat it was found to be bent at the muzzle end of the "D1" hoop; the "D1" hoop being a short hoop 78 inches in length which is assembled just forward of the trunnions. The gun was bent to such an extent that the muzzle drooped 0.9 inch in a vertical line with the gun in mounted position.

By the telltale method of indicating the exact location of the bend and its extent it was found that by setting the gun to run true at the breech end and also at a point 96 inches from the muzzle the runout would be equally divided between the muzzle end and the point of the bend. This was the most favorable condition for boring the liner seat in the gun without straightening before boring.

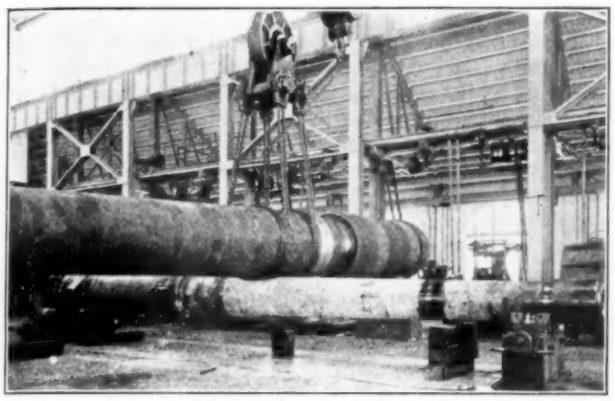
If the seat for the liner was bored in the position referred to the resultant thickness of the tube at the top after the liner seat had been prepared would be .055 inch in thickness and 1.45 inches in thickness at the bottom. At the point of the bend or two hundred and twenty-seven inches from the muzzle the tube would be 1.9 inches in thickness at the top and 1.0 inch at the bottom. The variation in the thickness of the tube was such that it was decided that the gun should be straightened before being bored for relining.

Since the straightening operation would call for the use of at least a two thousand ton hydraulic press with which this Arsenal was not equipped, inquiries were made of commercial concerns as to the cost of straightening the gun. Bids averaging approximately $1,500 were made for the first straightening operation with an additional charge of $1,100 for each subsequent operation that would be required; no guarantee being made as to how many operations would be necessary to obtain the desired result.

After considering the cost of the straightening operation, together with the cost of transportation, it was decided to improvise means and attempt the straightening of the gun at this Arsenal since the cost, if successful, would only be a fraction of the cost if it were necessary to ship the gun from the Arsenal. Both bidders for this work desired a tolerance in the straightening operation of 0.25 inch off its axis, which tolerance seemed reasonable, considering the fact that the thickness of the wall of the gun at the point of the bend was over ten inches; the built-up thickness consisting of three forgings, making two contact surfaces assembled with a shrinkage of approximately 0.025 inch.

The gun was suspended from a crane in a small electric

furnace to a point just forward of the trunnions and heated to a temperature of 950 degrees Fahrenheit. Current was applied to the electric furnace at noon on November 27, and the temperature brought up gradually until 7.45 p. m. on the same date, when the desired temperature of 950 degrees Fahrenheit was reached; this temperature be-



Straightening 14-inch Gun

ing maintained until 10.20 a. m. on November 28, when the gun was removed from the furnace. Eighteen minutes later the gun was in a horizontal position, supported at the breech and muzzle ends on roller rests. It was necessary to get the gun in this position with as little lapse of time as possible in order to prevent a lowering of the temperature of the gun by radiation.

At 10.40 a. m. the gun was set to center lines which had been previously scribed on both sides of the gun. The roller rests which supported the gun were at either end of a surface plate; making it possible to check up the center lines on both sides and ends of the gun with a gauge indicating from the surface plate.

At 10.43 a. m. a 16-inch gun, the weight of which, including the slings, was 294,300 pounds, was lowered from a crane across the 14-inch gun as shown in Figure 1, contact taking place at the intersection of hoops "D1" and "D2". The muzzle end of the 16-inch gun was supported on blocks in such a way that nearly all of the total weight of the gun was applied to the 14-inch gun which was being straightened. The center lines were checked with the 16-inch gun in position and indicated that the gun had been bent at the point of contact 0.125 inch . As soon as the weight of the 16 inch was applied, there was considerable snapping and cracking of the heated gun, showing that a considerable change was taking place due to the applied stress. In checking up the center lines care had to be exercised in taking into consideration an extension of the height gauge due to its expansion by coming in close proximity with a great mass of metal heated to such a high temperature.

The 16-inch gun was raised and lowered six times; a check being made each time to determine whether the correction of the bend which had taken place was permanent or not. At 11.13 a. m. the center lines at the point of contact indicated that the gun was bent in the opposite direction 0.25 inch. It was decided to allow it to remain in this position and cool; the 16-inch gun being removed at 10 a. m. on November 29. The center lines were again checked and found to be 0.04 inch out of true, which result was considered very good, especially in view of the fact that the tolerance desired by commercial concerns was 0.25 inch.

The temperature of the gun on November 29, at the time the 16-inch gun was removed, was approximately 150 degrees Fahrenheit. The gun was allowed to cool in position on the roller rests until December 4, when it was placed in the lathe and found to have a run-out of 0.14 inch at a point near the center of the gun about the middle of hoop "D1", or approximately fifty inches from the center of the trunnions. This run-out was recorded with a rest at 24 inches from the muzzle end. The muzzle rest was then moved back to a position about eight feet from the muzzle, when it was found that the muzzle end ran out 0.08 inch and at a point about midway of hoop "D1" it also ran out 0.08 inch in the opposite direction to the muzzle, thus dividing the run-out. A rest spot was turned true on the gun with this setting from which it is proposed to bore for the liner.

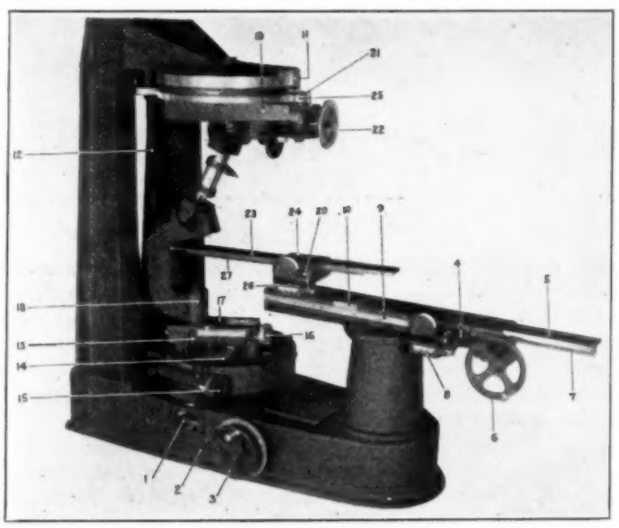
Before the straightening operation was attempted the gun was bored out at the breech end to a diameter of 16.6 inches for a distance of 20 inches beyond hoop "D1" with the gun running true at the breech end and 40 inches in front of the trunnion hoop; the muzzle end running out 1.25 inches when this operation was conducted.

The straightening operation is regarded as entirely successful and was accomplished at less than the cost of transportation if it had been necessary to ship the gun from this Arsenal.

Frankford Arsenal Notes

Target Relocater.—In the March-April, 1922, issue of ARMY ORDNANCE, there was described a Coincidence Target Computer, an instrument for use in mechanically determining the range and azimuth of a target from a reference point, by means of the usual base and observation stations employed by the Coast Artillery, the reference point generally being the point from which the fire of all the batteries forming the coast defense is directed.

Since the Target Computer is employed only for obtaining the range and azimuth of the target from the directing point, it is therefore necessary to determine the position



Target Relocater, Model E

from the gun batteries, that is, the range and azimuth of the target, or in military terms, to relocate the target in respect to the guns.

The Target Relocater, described in the following paragraphs, has been invented for use in conjunction with the target computer and mechanically determines the position

of the target referred to in the preceding paragraph. It consists principally of three elements, the directing point mechanism, the battery positioning mechanism and the relocating mechanism.

The directing point mechanism consists of the azimuth indicating device (1), which is housed within the base (2) and controlled by the handwheel (3) and the range mechanism (4), which consists of a bar (5), the movement of which is controlled by the handwheel (6). The rack (7) attached to the underside of the bar drives the counter (8) through a system of gearing. The scale (9) and the vernier (10) also indicate range and are provided only as a means for checking the action of the counters. The upper azimuth circle (11) is driven simultaneously with the lower azimuth mechanism (1) through a system of gearing connected by the vertical shaft (12).

The vertical centerline about which the azimuth indicating devices (1 and 11) rotate, represents the directing point.

The battery positioning mechanism consists of the guide (13) mounted upon the azimuth circle (14) which rotates simultaneously with the directing point mechanism. It is also capable of being oriented independently by rotating the knob (15). The knob (16) controls the movement of the slide (17) by which means the axis of rotation of the bracket (18), which corresponds to the battery position, is displaced from the axis of the azimuth circle (directing point) an amount corresponding to the distance between the battery and the directing point.

The relocating mechanism consists principally of the azimuth and range indicating devices (19 and 20) respectively.

The azimuth indicating device (19) consists of the pointer (21) which indicates degrees and the pointer (22) which is driven through a system of gearing and registers hundredths of a degree.

The arm (23) is secured to the bracket (18) and slides in the guide (24), and through the universal joints, causes the rotation of the arm (19) which carries the pointer (21) and contains the bearing for the gear (25), which is a part of the train that drives the pointer (22).

The guide (24) is pivoted on the end of the arm (5) and the relocated range counter (26) is driven by the rack (27) attached to the underside of the arm (23).

The scale of the relocater is 4,000 yards per inch and the least range indicated is 10 yards. The azimuths are indicated in degrees and hundredths of a degree.

Springfield Armory Notes

Rounds Counters for Aircraft Synchronized Machine Guns.—The Veeder Company of Hartford, Connecticut, have completed ten sample counters for the Browning Air-

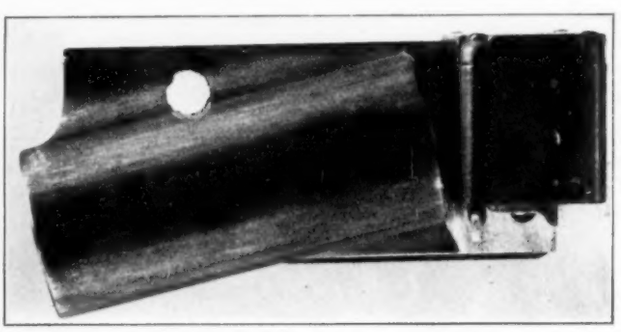


Fig. 1.

craft Machine Gun, Model of 1919. These counters are of a conventional design, specifically adapted to be mounted on the back plate of the machine and operated by a camrod, which is an extension to the barrel plunger and protrudes through a slot cut in the back plate. These counters operated very satisfactorily under test and required only slight modification in the gun in order to be used.

Fig. 1 shows the back plate with counter attached.

Springfield Armory has recently completed a rounds indicator to be mounted on the instrument board of the aeroplane and driven from the gun by a flexible shaft. The driving end is riveted to the cover of the gun and is driven by the belt feed slide. The mechanism is of the conventional ratchet design, the indicator end contains the reduction gears and means for quickly setting the pointer to any desired position.

Fig. 2 shows this mechanism.

Excellent results were obtained on a ten thousand round test with this indicator.

The first production lot of caliber .50 machine guns, consisting of 50 guns for the Army and 5 for the Navy, all of aircraft Model 1921 type, is practically completed by the Colt Company. During inspection these guns have been subjected to very rigid tests for functioning, endurance, safety, and interchangeability and have passed all these tests in a manner which reflects great credit upon the manufacturer. They will be shipped in the near future to designated stations for service tests which will probably determine the utility of these weapons and the extent to which they are likely to be needed in the future armament programs of the services concerned.

Drawings for these guns, which are considered the basic aircraft type, have been nearly completed by the Experimental Department, and will soon be submitted to the Ordnance Office for approval. Data for training regulations is being assembled and will be prepared in pamphlet form as rapidly as practicable. This pamphlet, however, is to include data on the basic water-cooled and anti-aircraft guns as well as that specially pertaining to the aircraft model, and so will not be completed for several months.

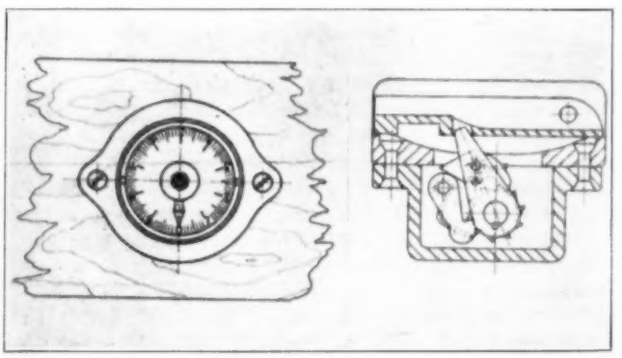


Fig. 2

Design of the U. S. Aircraft Machine Gun, which is the improved model developed by this Armory to fulfill as nearly as possible the requirement for an ideal synchronized machine gun, is considered practically complete, subject to suggestions for improvement which may be made by the Air Service. Work on this project is now confined to preparation of detail and assembly tracings, which condition will continue until the Air Service makes its recommendations. While this gun is intended for use as a fixed synchronized gun, the possibility of its being used as a flexible gun has been kept in mind and a suitable spade grip and hand trigger mechanism has been provided, the spade grip being constructed to include a counter in the same way that the back plate does. Use of this or any other belt-fed gun depends principally upon whether satisfactory arrangements for handling the belt can be provided. Some preliminary study of this problem has been conducted, but so far without definite satisfactory results.

* * * * * * *

Brig. Gen. F. H. Phillips, Executive Officer of the National Rifle Association, visited this Armory on November 24, 1922, in connection with the manufacture of the National Match Rifles. The Armory is on such a small production basis that it is deemed advisable to proceed with the manufacture of the National Match Rifle at as early a date as possible.

* * * * * * *

Acting under instructions of the Chief of Ordnance, Mr. John C. Garand, of this Armory, visited Fort Benning and Fort Riley during November to demonstrate his semi-automatic rifle before the Infantry and Cavalry Boards. For these firings Grade 2 ammunition was furnished and except for a few minor corrections the rifle functioned satisfactorily and it is believed made a favorable impression.

Two military engineers from the Japanese Imperial Army, Mr. T. Koyama and Mr. K. Ishii, were given permission by the Secretary of War to visit this Armory for the purpose of studying the operations in connection with the manufacture of the United States Rifle, Cal. .30, Model of 1903, and the bayonet. They arrived here on December 14, 1922, and stayed for three days.

* * * * * * *

During a recent visit of Capt. S. G. Green, Ordnance Department, at this Armory, the difficulty experienced by fouling of the blank firing attachments of the Browning Automatic Rifle was overcome by him by the application of water, thus washing out the carbon. The Ordnance Office has authorized the construction of a number of blank firing attachments with a number of different rifles to ascertain if the fouling could be eliminated by washing with water and also the construction of several magazines. Two of these magazines have been tested with satisfactory results and others will be tested upon their completion, and if the report is favorable will be sent to Fort Benning for further test. The application of water to the firing attachments gave satisfactory results.

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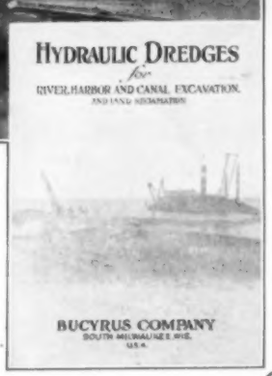

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WHAT IS AN ORDNANCE OFFICER

Continued from page 226.

To enhance these qualifications by becoming up-to-date specialists on any particular matériel, or on any one or more of the four programs discussed in this paper is no doubt a problem as difficult to handle in the administration of the Ordnance Office as it is for the individual officer. The need for Ordnance Officers who are specialists, therefore, throws a serious and difficult obligation both on the Ordnance Office and on the Commanding Officer of every Ordnance establishment in the assignment of officers to such duties as will not jeopardize their advancement in the branch of work which they desire and are particularly qualified to follow.

Finally, be it emphasized that the impelling spirit of every Ordnance Officer is one of *Service;* the more splendid his qualifications as an executive the larger and more effective his service.

No better summary of the technical qualifications of an Ordnance Officer can be found than that given by General Williams in an article entitled "The Ordnance Problem" in the July-August, 1922, issue of ARMY ORDNANCE:

"The officer must be thoroughly educated technically in order to insure that the latest developments in chemistry, metallurgy and engineering are applied to munitions, designs and procurement. He should be trained to administer the tasks of constructing and operating manufacturing plants and depots in an efficient and economical manner. He must be well acquainted with the needs and troubles of the actual users of munitions. He must understand the War Plans of the Government in the matter of munitions, be acquainted with the steps proposed to meet them, and be prepared to execute efficiently the agreed upon solution."

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